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THE GREEK CONVENT OF ST. GEORGE, PALESTINE.—[See page 35.]

Psychical Research*

The Attack of Modern Science on the Realm of Occultism

By J. Arthur Hill

It is related of Mme. de Staël that she did not believe in ghosts, but that she was afraid of them all the same —"*je ne les crois pas, mais je les crains.*" The witty Frenchwoman's epigram contains deep psychological truth; for our emotions are not ruled by our reasoned beliefs. And, in addition to its true psychology, it accurately describes the attitude of the average man, though he may not confess it so frankly. We don't believe in ghosts, oh, no, not really *believe* in them. But we are at times a little—just a little—afraid of them; say, for instance, when going to bed at two in the morning (at which hour, according to Napoleon, courage is at its lowest ebb) up the gloomy staircases and in the draughty corridors of an old and lonely house, with the wind soughing and sobbing and wailing in the trees outside—like the wraith of poor Cathy in "Wuthering Heights." At such times we have inner qualms, step we never so boldly.

The recent advance in certain by-paths of science, however, seems likely to go far toward effecting a change in popular opinion and popular feeling. The ghosts, like everything else in this extremely scientific age, are now being studied and examined, and photographed and dissected (or would be, if they had any insides to dissect), and the prospects are that before very long, we may get so well acquainted with these *animulae vagulae* that we shall no longer be afraid of them. Then we shall be able to reverse the epigram; instead of disbelieving yet fearing, we shall believe but shall not fear. This consummation may be displeasing to the orthodox haunting ghost, whose business is (like the Fat Boy's in "Pickwick") to make our flesh creep; but, on the other hand, it will meet with the approval of all sensible and well-disposed spirits, such—for example—as Mr. Stead's friend Julia, of whom we have lately been hearing so much.

The "spirit" question, however, is the wrong end of the subject to attack. Of course, when an apparition does turn up it is the percipient's scientific duty (if he can keep his wits about him sufficiently to do it well) to observe it, to make careful notes at once, and to get them signed—along with a doctor's certificate of sobriety—by corroborating friends. Then, if the person represented by the spook is afterward found to have died at the time of the vision, we have good evidence for some kind of supernormal agency. Or if—as is most likely—he did not die; if, indeed, he was in specially good health and spirits at the time; if, in short, our hallucination was due to indigestion (as the doctor probably assured us), we naturally feel a mild regret that the Society for Psychical Research should have lost a promising "case," but, on the other hand, we have at least retained our friend, who—perhaps equally naturally—will be apt to regard our aforementioned regret with a feeling akin to resentment. But, even in cases of veracious hallucination i. e., hallucinations which seem somehow connected with distantly-occurring events, and which are therefore "truth-telling," even in these cases, the scientific value of the phenomenon itself is perhaps less than that of many apparently less important happenings. For it is not the mere establishing of the actuality of an alleged phenomenon, that constitutes its value to pure science. It is the linking of it up with facts already known; the fitting of it into the mosaic of already organized knowledge; the bringing of it into the domain of law; it is here that the main business and interest of the philosophical scientific men are to be found. And, in the case of ghosts, this linking up, and fitting in, does not seem likely to be an easy matter, even if the facts are satisfactorily established.

It was therefore with deep wisdom that Sir Oliver Lodge, in "The Survival of Man," which is the latest important pronouncement on the subject, decided to begin at the other end. Instead of plunging into the description of phenomena which puzzle us because they seem so out of relation with our scientific knowledge, he starts by giving a lengthy and careful description of some experiments of his own which seem to establish the fact of thought-transference or "telepathy." In these very matter-of-fact and unghostly experiments, the chief parts were played by two young ladies who were employed by a Liverpool firm, of which Mr. Malcolm Guthrie, J.P., was head. One of them—the receiver or "percipient"—was blindfolded, though as an aid to passivity of mind rather than as a precaution. The other—the "agent"—concentrated her mind on an object selected by Sir Oliver, trying to impress the idea of it on the mind of her friend. Care was taken, of course, that the latter was afforded no opportunity of seeing the object, or of gleaning any information of its nature by normal means. Many of the experiments were made with ordinary playing cards; for, by this means, the likelihood of chance coincidence could be mathematically determined. In one series which Sir Oliver quotes, the successes were ten out of sixteen. The chance of this occurring by accident can be shown to be less than one in ten million.

From this we go on to telepathy at a distance. Recent experiments between Miss Miles and Miss Ramsden, carried out in accordance with suggestions made by Prof. Barrett, indicated clearly that some supernormal agency was at work. The distance between the experimenters varied, as one of them was traveling about; during part of the time it was about four hundred miles. Often, the exact idea sent by the agent was received by the percipient, who sat alone, at a specified hour, waiting passively for ideas to drift into her mind. At other times, the message received was not that which had been consciously sent, but nevertheless represented something which had been occupying the agent's mind during the day. From this it appears that the agent's subconsciousness, as well as the ordinary conscious level of the mind, may have something to do with the process.

With this in mind, we go on to consider a different class of phenomena, viz., what is called by spiritualists "trance-mediumship," and by psychical researchers "motor automatism with obscuration of the supraliminal consciousness," or other terms to that effect.

It is a common thing for a sitter with a trance medium to be told the most astonishingly correct and intimate details of his family life, the names of his relatives, and so on, although, so far as he knows, he is an entire stranger to the medium. The intelligence, or control, purports to be a guardian-angel sort of spirit, who habitually speaks through this medium, and who says that he or she is getting the information from spirits who are the sitter's deceased friends or relatives. Sometimes one of these latter is allowed by the "guardian-angel spirit" to take personal possession of the medium's body, and thus to speak directly. In such a case the astonished sitter (i.e., if he is a novice) finds himself addressed in characteristic fashion by some dead person, reminded of little experiences which they had shared in life, and is perhaps ultimately convinced that he is veritably in direct communion with the disembodied mind of his relative or friend. When the medium wakes up, she (it is usually a "she") has absolutely no knowledge of what her vocal organs have been saying.

Now, how are we to set about explaining all this? The first thing to make sure of is, of course, that ordinary fraud is excluded. This is usually a fairly easy matter. When the sitter can question the "spirit" (as in these cases he always can) it is easy enough to get satisfactory assurance that common trickery is not the correct explanation; for questions can be asked concerning family matters, or mutual experiences, of which the medium could not be normally aware, even assuming the employment of skilful and energetic detectives. Moreover, in several cases known to me, the sitter gave either a false name, or no name at all. In one of these cases, the sitter was a friend of mine, living two hundred miles from London, where the sittings took place, and there is no reason to suppose that he was in the least degree known to the medium. He was not a spiritualist, had no spiritualistic friends, and had never sat with a medium before. Yet the guardian or "guide" gave my friend's two Christian names, with a good deal of true detail about his life, and at the second sitting, two days later, he was greeted by an intelligence purporting to be his recently-deceased mother, who alluded by name to all the near surviving relatives, with appropriate comment and attitude, and gave other evidence of a characteristic and convincing nature. My friend had gone into that room a sceptic, bent on "showing up" these tricky mediums; he came out absolutely convinced that he had spoken with his deceased mother. I express no opinion, except that some supernormal explanation seems to be required. (I may also remark that this case, considered in full detail, is much more evidential than this necessarily short description can indicate. It is described in full in my just-published book, "New Evidences in Psychical Research." William Rider & Son, Ltd.)

Fraud being excluded, we turn to other possible theories; and, bearing in mind the fact of thought-transference or "telepathy"—already established by experimental methods—we surmise that the medium has somehow read the sitter's thoughts. The fact that the trance-control's remarks do not coincide with what we were thinking of at the time, is no obstacle, for, as we saw in the case of Miss Ramsden, it is not always the agent's *conscious* thought that is reproduced. The medium's trance-consciousness may be able to rummage among our memories, selecting those which stick together round a given personality. As to the verisimilitude of the characterization, this is easily comprehensible, for it is well-known and continually-observed fact that in the hypnotic state many subjects are excellent mimics, and hypnosis is undoubtedly related to "mediumistic" trance.

It follows, then, that nothing more than thought-transference need be supposed, so long as the medium tells us nothing except what we already know. But, what shall we say if things are told us—things characteristic of the *soi-disant* spirit—which have never been known to us, but which on investigation turn out to be true? Well, this certainly complicates matters, but, knowing that telepathy can be effected over great distances, as in Miss Miles's and Miss Ramsden's experiments, we are able to suppose that the fact in question has been somehow telepathically gleaned from some distant mind. It is, however, clear that in making this supposition we are treating two cases as analogous, which differ in important features. Miss Miles and Miss Ramsden are well known to each other, are, in fact, friends: and, though the consciously-attempted message sometimes failed, another (which was not "sent") taking its place, it must nevertheless be borne in mind that the two experimenters were thinking of each other frequently, and that there was thus a certain *rapport* between them. Whereas, in some of these trance messages, the person whose mind must be supposed to have supplied the information is a person who has never seen the medium; is not known by the medium; is unaware of a sitting being in progress, and therefore is not thinking of anything of the kind; is indeed perhaps unaware of the medium's existence, and hostile to psychical research and all its works. The conditions are therefore very different from those of experimental thought-transference. Still, this latter fact having been established, and its possible range not yet being satisfactorily defined, we are bound by the law of parsimony to work telepathy for all it is worth, before turning to other and more far-fetched-seeming hypotheses. So long, therefore, as any living mind contains a fact which is retailed by a control as evidence of its identity, we must suppose that it may be a case of telepathy from that living mind.

I say we must suppose that it *may* be. It does not by any means follow that it *is*. Some of the cases quoted by Sir Oliver Lodge as occurring in his own experience with Mrs. Piper, though possibly explicable by telepathy, are nevertheless strongly suggestive of the action of a disembodied intelligence. For example, a "spirit-communicator" in Mrs. Piper's trance claimed to be the deceased son of Mr. Rich, at that time postmaster at Liverpool. This entity wished a message to be sent to his father, who was said to be worrying specially about his son's death. The sitters knew Mr. Rich slightly, but knew nothing about the matter dealt with in the message. This latter, however, was duly delivered, and turned out to be appropriate to and characteristic of, the deceased young man. The exceptional worry or grief was due to a slight estrangement, which would have been only temporary. If we are to invoke telepathy in this case (and it is only one of many similar ones) we are driven to the curious supposition that Mr. Rich subconsciously sent a telepathic message to Mrs. Piper (whom he did not know, and who did not know him) and that this message was dramatized and returned. In other words, that he sent a deceptive message to himself—*via* Mrs. Piper, and by means unknown to science—without knowing anything at all about it! It seems almost too easy to believe in the *prima facie* explanation (i.e., genuine spirit communication) as in such marvelous telepathic exploits as this.

But is there—it may be asked—any way of putting it to the proof? Cannot telepathy be shut out, somehow? Cannot crucial tests be devised? On this very important point several acute brains have been cudgeling themselves for many years.

It was at one time thought that the best test would be the posthumous reading—through a mediumistic communication—of a sealed letter left in the keeping of a friend. Such a letter was left with Sir Oliver Lodge by Mr. Myers, but the attempt by a *soi-disant* Myers-communicator to give, through Mrs. Verrall's automatic writing, a reproduction of its contents, was a complete failure. It is now recognized that the test is not a good one: for even if it succeeded, it would not yield proof. It would still be possible to suppose that the deceased had, before dying, unconsciously "telepathed" the contents of his letter to some person or other, and that, when a medium somewhere produced

* Reproduced from *Knowledge.*

the message correctly, it was through telepathy from the subconsciousness of this hypothetical person. Or, again, the letter, though sealed, might be read "clairvoyantly." Some such power is often alleged, and there is a good deal of evidence in its support. Further, is it not too much to expect that a spirit will remember what the letter contains? Sir Oliver Lodge has not prepared such a letter, for he is quite sure that he would forget what he had written. Probably most people will feel similar doubts about their *post-mortem* recollection of such matters.

The sealed-letter test, then, is given up as unsatisfactory. What shall we turn to next?

It was thought by Mr. Myers and Prof. Sidgwick that it would be rather good evidence if the same message could be obtained from the same spirit through two or more mediums. Some experiments in this direction were made, apparently but without much success. After the death of these two leaders in the research, it was natural to expect that they would themselves try something of the kind from "the other side," in order to give us evidence of their continued existence. And, as a matter of fact, this seems to have happened. The same message, almost word for word, was received from a Sidgwick-control through Mrs. Thompson, in London (sitter, Mr. Piddington, Hon. Sec. of the Society for Psychical Research), and Miss Rawson, in the South of France. But the telepathic difficulty again arises. The two messages were not exactly simultaneous. Is it not possible that Miss Rawson's subconsciousness made up the message (it was one giving some instructions to Mrs. Sidgwick about the preparation of her husband's "Life"), and then telepathed it to Mrs. Thompson? It is of course necessary to suppose also, that the subconsciousnesses of the two mediums were in league to represent the message as coming from Dr. Sidgwick. But if the heart of man is deceitful above all things, and desperately wicked, there is no knowing to what depth of sin these newly-discovered "subliminals" may descend. We must hold them guilty until we have proved them innocent. In this case, once more, then, telepathy is not excluded.

At this point the ingenuity of the earthly investigators seemed to come to a stand. There seemed no way of getting round this omniscient and omnipotent telepathy. It seemed impossible to devise any experiment which should shut out with reasonable certitude the agency of minds still in the body. Just about this time, however, a curious thing happened.

For some years after Mr. Myers's death in 1901, automatic writing had been regularly produced by several people of social and educational standing—not professional mediums, or even spiritualists—who were more or less in touch with the Society for Psychical Research, and whose script purported to emanate partly from the surviving mind of F. W. H. Myers. Chief among these automatists is Mrs. Verrall, Classical Lecturer at Newnham; others are Mrs. Holland (an Anglo-Indian lady, who did not know Mr. Myers) and Mrs. Forbes, the widow of a well-known judge. These scripts contained much evidential matter, but it was usually open to the telepathic explanation, though some of it admittedly strained that explanation rather severely. Still. telepathy was *possibly* the true theory. But, in 1906, it was discovered by Miss Johnson (the Research Officer of the Society for Psychical Research) that there were curious concordances in these scripts, concordances which apparently had been going on for some time. It was found that one script, say Mrs. Verrall's, would contain a piece of writing which was apparently meaningless, and which was so treated by the automatist, while another script, say Mrs. Holland's, written about the same date, would contain a message equally meaningless in itself, but which, when compared with the similar one in Mrs. Verrall's script, produced the most startlingly good sense. Here, then, apparently, was found evidence of initiative "on the other side," for none of the living investigators had thought of this plan of splitting a communication up and giving it piecemeal through different automatists. (*See Proceedings of the Society for Psychical Research*, Vols. XXI and XXII).

These remarkable phenomena are, however, still not quite conclusive. Perhaps the ingenious and sportive subliminals of the automatists concerned have arranged an elaborate system of impersonation, telepathing these message-fragments to each other, while the normal consciousnesses remain ignorant of all this below-decks cross-firing. The hypothesis cannot be entirely put aside; though it seems very improbable to those who have made a careful study of the whole mass of evidence. As Sir Oliver Lodge has said, it is too early to formulate dogmas, or even to express opinions (on the spiritualistic question) except in hesitating and tentative fashion. But the evidence now certainly seems sufficient to justify the holding of at least a working hypothesis that in these experiments the minds of "dead" persons are really playing a part.

This, however, is a very different thing from an acceptance of "spiritualism," with all its crudenesses and follies. The spiritualists—or most of them—accept any sort of trance-ravings or automatic scrawlings, as genuine "messages" from "the beyond." Psychical research, on the other hand, critically examines the content of the messages, applying the most drastic tests before even admitting other than known causes. If the communications contain nothing that is not known to the medium, psychical researchers dismiss them as of no interest; unless, indeed, there is a cross-correspondence involved—i. e., the same message, or a related one, being given through another medium. If the medium's own knowledge is undeniably insufficient to account for the facts, then telepathy is invoked, and is stretched to a fearsome extent, amid the violent diatribes of the spiritualistic press, which stigmatizes the Society for Psychical Research as a Society for Suppressing Knowledge. If telepathy begins to seem insufficient, some few bolder spirits of the Society (incarnate ones) venture on the tentative hypothesis of "telepathy from the dead;" but with careful hesitancy, leaving the door open behind them in order that they may flee back to the safety of former and more orthodox views, if further investigation should render the new tentative hypothesis untenable. This perhaps undignified but certainly wise position is that which is at present occupied by Mrs. Sidgwick (the ex-president of the Society), Sir Oliver Lodge, and other leading members of the Society for Psychical Research. The present writer, who is also a member of the Society in question, adopts a similar attitude. Personal investigation has convinced him of the truth of Hamlet's well-worn remark to Horatio, and he is even inclined to think that some of the evidence justifies us in thinking that (to be Shakespearean once more) not only can we call spirits from the vasty deep, but that sometimes they will *come* (though of their own free will) when we do call for them.

It is a difficult subject, not suitable for everyone. Emotional and unbalanced people should be warned off. Even religious people are doubtfully desirable: the investigation should be carried on, as far as possible, in the pure dry light of science, as it has been in the past, by men like Sidgwick, Gurney, Myers, and Hodgson. We want no recurrence of witchcraft and superstition, of which, perhaps—after the materialistic extremes of nineteenth century science—there is some danger, the pendulum of popular opinion being apt to swing from one side to the other. But, this said, we may follow up our researches with an easy mind. We are certainly on the track of something, whether (in Prof. Barrett's phrase) it be a "new world" of being, or not. Careful and honest and patient investigation will no doubt yield its reward; but no sudden revelation is to be expected or desired. It may require the labors of many generations to unfold the full significance of the discoveries which are now being made. For it is not only in the (possibly) spiritistic direction that our pioneers are making progress; we are also finding out much concerning the unsuspected powers of the human mind (telepathy, clairvoyance, and so on) while it is still manifesting itself through a material brain in the ordinary earthly life.

The Monasteries of Palestine

Historic Buildings, Rich in Legend-Lore

By Harold J. Shepstone

ONE of the most striking features of Palestine is its numerous monasteries and convents belonging to various religious sects. Many of them are remarkable edifices, built on lonely and isolated sites, famed for their connection or supposed connection with sacred history. As the result of this we have wonderful structures on mountain tops, on the edge of steep precipices, in deep ravines, on the banks of streams and in the heart of the desert and wilderness. When you behold them you marvel at the daring of their architect and builder, for their erection must have demanded no small amount of engineering skill. The transportation of the heavy building stones of which they are constructed to some of the more inaccessible sites must have been in itself a formidable task. Then came the erection of this mass of material into position—feats which must have frequently taxed the resources of their builders, more particularly when we remember that they represent the work of the ancients, the edifices in some cases dating back to the early centuries. Then they were built for defence, strong enough to withstand lengthy sieges and even to-day, in the more out-of-the-way parts of the country, the monasteries are still liable to attack from hostile tribes.

Perhaps none has had such a checkered career as the Convent of Mar Saba, belonging to the Greek Church, clinging to the sides of a precipitous gorge in the very heart of the wilderness. It lies ten miles southeast of Jerusalem and is reached from the Holy City by horseback, the road being too steep and rugged for a carriage. It is certainly a desolate and dreary spot—the last place where one would expect to find a habitable dwelling. The convent occupies a site on the western side of a great canyon. It is reached, not as in most other cases by ascending to it from below, but by descending to it from above. One cannot enter without the written permission of the Greek Patriarch at Jerusalem, and on no account are visitors admitted after sunset. Then the monastery is rigidly closed to the fair sex. At the entrance, however, there is the Women's Tower, where female pilgrims may lodge.

Descending two flights of steep steps one comes into a little courtyard where St. Saba, the founder of the convent, is buried. Near by is the Chapel of St. Nicholas, hewn out of the solid rock, as are also the cells of the monks. Behind gratings in the recesses are heaps of skulls and bones, grewsome reminders of the stormy days when the monastery was frequently attacked and the monks put to death. The monastery church is a very attractive and pretty little chamber, behind which lie the cells of the monks. Then there is the lion's grotto, reached by a rock-hewn passage which leads into a cavern. The legend runs that one day the saint found his cave occupied by a lion, but nevertheless began fearlessly to repeat his prayers and then fell asleep. The lion dragged him out of the cave twice, but the saint assigned him a corner of the cavern, after which they lived peaceably together.

The various buildings rest on small areas formed by the aid of massive buttressing walls built up from below, terrace above terrace—certainly a clever and skilful piece of engineering work. There are grottoes and tiny gardens of flowers and fruit trees. At the present time the monastery is occupied by fifty monks who lead an ascetic life, eating little else than vegetables and fasting frequently. Their principal occupation, besides the care of a few lunatics and refractory monks who are imprisoned there, is the feeding of the wild birds of the surrounding wilderness. The huge black ravens that dwell there are so tame that they will eat out of the fathers' hands..

The monastery is one of the oldest institutions of its kind in the world, having been founded so far back as the fifth century. In the sixth, seventh and eighth centuries it sustained murderous assaults by different Arab tribes. In 614 it was plundered by the Persian hordes of Chosroes, who killed all the monks, destroyed their church and burnt their manuscripts. Hostile tribes have lain siege to it for months at a time, hoping to starve out its inmates. It was after one of these sieges, just when the principal was about to open the door and make the best terms possible with his enemies that he espied a relief force coming to his rescue. For six months the monks had lived on a handful of millet and a cup of water a day. But even now the monastery is not free from attack. In 1834 it was pillaged by a band of roving Bedouins..

Those visiting the monastery should endeavor to spend a night here, for it is an experience not easily forgotten. The accommodation is rather poor and the only provisions obtainable are bread, fruit and wine, but in the kitchens provided one can cook his own food. Like all other institutions of this description in the East no payment is asked, but custom has established a tacit understanding that a suitable money recompense be made. When darkness has fallen one should take a walk on the terrace and look down into the valley. If it is a moonlight night you are overawed at the convent's singularly desolate situation. The rock falls away perpendicularly to a depth of 590 feet and all is wild, barren, and bare. Nothing disturbs the silence except the occasional laughing of the hyena.

In the wild gorge of the Der Wadi el Kelt, at no great distance from Jericho, stands the Greek convent of St. George, said to mark the spot where the ravens brought food to Elijah. This monastery was formed by walling up a cavern in the rocks, one of the many which abound in this locality, where, in olden times, anchorites lived.

Photograph by American Colony, Jerusalem

Greek Convent at Mar Saba

This cavern, with the others near by, formed in the fourth century the "Laura" of John of Couziba. In the sixth century a monastery stood here which fell into decay and was restored in the time of the Crusaders. The interest in the locality grows out of the doubtful tradition that this gorge was that of the Cherith where Elijah was nourished by the water of the brook and the ravens that brought him food. It is commonly called the Cherith and water flows in the bed of the stream below the monastery for the greater part of the year.

A most unique and interesting convent is the one belonging to the Greek Church, which is perched, like an eagle's eyrie, high up on the perpendicular face of the Mount of Temptation, lying a short distance to the west of the site of ancient Jericho. There are still traces of twelfth century frescoes representing Christ tempted by Satan. In the time of the Crusaders the convent was occupied by the Brothers of the Quarantine, that is to say, the forty days. It was then controlled by the Canons of the Holy Sepulchre. Later it fell into decay. Since 1874 it has been occupied by Greek Church monks and is one of the shrines visited by Greek Church pilgrims. It is a stiff climb up to the convent and the transportation of the heavy stones of which it is built up the steep precipice was certainly no easy feat. Passing through the convent one can make his way to the top of the mountain where are some Roman ruins. This eastern face of the mountain has many caves which were occupied in the early centuries by hermits. The weird and desolate aspect of the entire locality certainly lends force to St. Mark's graphic description of the temptation of Christ when he says that He was with the wild beasts. From the convent, but more especially from the top of the mountain, there is an inspiring view of the entire Jordan valley in its lower stretches.

A short distance from the west bank of the Jordan stands the Convent of St. John, also belonging to the Greek Church. It is a massive pile of white buildings capable of affording accommodation to three or four thousand people and is a place of great activity during the Epiphany services. It was restored in the twelfth century by the Crusaders. Remains of frescoes and mosaic work can be seen in the crypt of the modern building, which rose on the site of the former structure in 1882. The night before the Epiphany great numbers of pilgrims, mostly Russian peasants, come to the convent. Clad in white shrouds they dip themselves into the waters of the Jordan. The shrouds are then taken home and preserved for the burial of the owner.

On the banks of that dreary expanse of water—the Dead Sea—stands the Convent of St. Jerasimus. It is called by the natives Der Hadjla, the modern form of the ancient name of Beth Hogla mentioned in Joshua. The present building is a modern structure built on the site of an older edifice. There can be seen traces of frescoes and mosaics from the time of the Crusaders. About a mile from the monastery is a lukewarm spring, around which the monks have planted a garden.

Halfway between Jerusalem and Bethlehem, on the saddle of a hill, stands the Monastery of Mar Elias, one of the best known, perhaps, of these institutions. From the terrace a fine prospect view of Bethlehem is obtained from the south end of Jerusalem on the north. It is thought to have been founded by the Emperor Horachius. It was restored in the twelfth century during the Crusaders' régime. It was, however, at a later date that tradition connected the site with circumstances in the life of Elijah when he fled from the wrath of Jezebel. On the side of the road opposite the convent is shown a rock with a depression in its surface said to have been caused by Elijah when he lay down to sleep, from which the angel awoke him to strengthen him with food for the journey to Horeb.

In and around Jerusalem there are a number of monasteries, the two most interesting being the Latin Convent of the Dominican Fathers and the famous Greek Convent facing the entrance to the Church of the Holy Sepulchre. The first named is located in the midst of spacious grounds on the east side of the Nablous road a short distance north of the Damascus gate. About thirty years ago traces of old ruins were found on these grounds which where soon after acquired by the Dominicans. Excavations disclosed what were thought to be the remains of a great basilica built in the middle of the fifth century by the Empress Eudoxia in honor of St. Stephen, who is believed to have suffered martyrdom on this spot. The Empress was buried here. It was in ruins in the time of the Crusaders, who, however, rebuilt it, but themselves again destroyed it on the approach of Saladin.

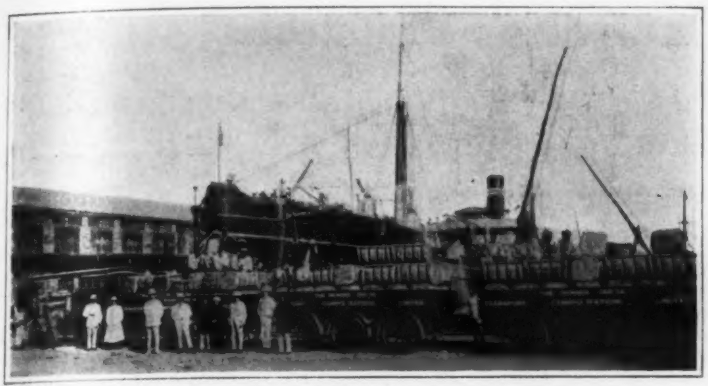
The present church was built on the ruins of the ancient edifice, the plan of which was followed to a large extent. They also built the fine convent adjoining the church. There is in the convent one of the finest libraries in Jerusalem and an interesting museum. The aim of the Dominicans in taking up their abode in Jerusalem is to study the Bible in its own land and language. There are among them some of the first of archæological scholars. In the winter months there are free weekly lectures which anyone can attend, giving him an opportunity to hear great specialists. The Greek convent, which faces the entrance to the Church of the Holy Sepulchre, is one of the smaller of the several Greek monasteries to be found in the Holy City. The open space above the ground floor affords a good place from which to view the Easter ceremonies in the church quadrangle. It is an abode of Greek monks.

No description of these Eastern institutions would be complete without a reference to the Carmelite Monastery, belonging to the Latins, on Mount Carmel. It is often referred to as the "Mother Convent" and is conspicuously situated on the promontory in which the ridge of Carmel terminates and overlooks the town of Haifa and the bay on the opposite side of which Acre can be descried. It is reached by a half hour's carriage ride from Haifa, the road winding by long sweeps up the mountain side. Many hermits lived in the caves in this neighborhood in the time of the Crusaders and a monastery stood here which was destroyed in 1821 after the Greek revolt by the Pasha of Acre. The fine large new buildings erected on the ruins of the old accommodate about twenty Latin monks of the Carmelite brotherhood. Large hospitality is extended to the numerous pilgrims who visit the place. They are accommodated on the spacious ground floor, while the monks have their quarters on the floor above. It is interesting to walk through the roomy corridors, the walls of which are hung with a great number of religious prints and paintings. From the terraces above a splendid view of sea and mountain and plain opens up to one's gaze. A short distance from the convent a large cave called the School of the Prophets can be inspected. Traditions says the Holy Family found shelter here on their return from Egypt.

The Telephone in Japan

The telephone was inaugurated in Japan twenty-one years ago; prior to that time it was not regarded as useful, but it is now looked upon as one of the necessary means of communication. It is installed at many local points besides the representative prefectural cities. At the time of the inauguration of the telephone, the Government authorities did their best to obtain as many subscribers as possible, but they had to open with 155 subscribers in Tokio and 45 in Yokohama. Calls at that time were only about one thousand daily. A few years later the public began to appreciate the usefulness of the telephone and it became increasingly popular. Consequently the Government extended the system in 1896 and again in 1907, in order to meet the general demand. About thirty million yen ($14,000,000) have hitherto been expended on the telephone system; telephone wires now connect over 1,600 cities, towns and villages; there are over 700 exchanges with about 126,000 subscribers. The wires entend over 440,000, miles, and calls per annum exceed 400,000,000 the annual revenue reaching 10,000,000 yen.

The growth of the telephone system is undoubtedly a source of satisfaction to Japan; but compared with that in Europe and America it is still far behind in popularity and the extent of its use. The number of applications for telephone connection is far in excess of the number of installations which the authorities can undertake with the fund at their disposal. With each application 15 yens must be deposited. The Government's project is to install 61,230 stations by 1912, with an estimated outlay of 18,200,000 yen. The excess of demand over supply has given rise to the telephone brokerage business. At one time the transfer of the privilege of installation commanded the price of as high as 800 yen or more. In the summer of 1909 the authorities undertook the installation of 300 connections in Tokio, for those who offered 200 yen, and this had the effect of pushing down the "market-price" of the transfer to about that figure. The yearly charge for telephone connection varies between 60 and 40 yen, according to location.—*Japan Magazine.*



Gasoline Road Train With Load of Sixteen Tons of Cotton at the Bombay Docks.

Team of Thirty Donkeys Hauling Thirty Hundredweight. In Background Fourteen-ton Gasoline Road Train.

Gasoline Road Trains in India and Australia

OUR illustrations show some examples of a mode of transportation which is gaining considerable ground in some of the British colonies. The first photograph shows a gasoline road train at the Bombay docks, loaded with sixteen tons of cotton which has been conveyed to port from the mills for shipment. The second illustration, a scene from Australia, brings out graphically the advantage of this method of trucking, over the old-fashioned mule team. The load of the gasoline train here is fourteen tons, that of the truck drawn by thirty donkeys is only thirty hundred-weight.

The gasoline road trains, which have been sent out to India have worked in very diverse conditions in various kinds of country. One of the severest trials in the way of steady pulling against an adverse gradient was in Assam. A train was here employed for the Indian State Railway service on the Gauhati-Shillong cart road and had to negotiate some very steep hills. It comprised a 100 horse-power locomotor and three 5-ton railers, which were used to convey all sorts of heavy goods. The total distance covered was 64 miles, of which the first 7 miles are practically flat. Thereafter there is a continual succession of long and steep curved hills, ranging from one to nine miles in length without a break. The curves consist of S-shaped and hairpin bends, all on hills and within a few hundred yards of each other all the way. The worst curve is from 15 to 20 foot radius on a grade of 1 in 9. The average gradient for the whole distance is about 1 in 17, and the worst long gradient 1 in 9.3; shorter gradients of 1 in 7 also occur. The total rise is from 180 feet above the sea level at Gauhati to 4,928 feet above the sea level at Shillong, but the train had to ascend an aggregate vertical height of 6,360 feet on each journey. The breadth of the road is from 12 to 14 feet. It has a fairly good surface, but it is dusty, and bridges are numerous.

The Indian State Railway officials state that the train proved a most efficient transport vehicle in carrying capacity, speed, hill climbing, braking, cheap working costs, general reliability, and continuous pulling. The train carried various loads up to 14½ tons with ease, and there were no accidents or breakages during all the trials. Previous to the trials motor lorries, traction engines, etc., had been tried on this route, and all had been a failure owing to their inability to get round the sharp corners, or to take a paying load up the hills. The cost of the road train service per ton mile ranged according to the loads carried, from slightly over ½ cent to 1 cent per mile. The chief engineer to the Indian Railway Board consequently recommended that six trains should be put on this route alone, but the scheme is in abeyance till the necessary money has been voted in the Indian estimates.

These road trains have been used on the plains of the North Western Provinces of India for carrying passengers. The train was kept running for seven days per week, doing 50 miles per day. The average daily working expenses, including driver's and locomotor assistants' wages, natives, gasoline, oil, stores, depreciation and repairs was about $15. In Calcutta, the train was employed for transporting whatever goods were offered over roads with surfaces varying from good to distinctly bad.

This English gasoline motor system of road transport is said to be the most efficient type of road traction yet evolved, its working capacity being enormous. There is no hauling or trailing as with ordinary form of traction engines and trailers, but each vehicle of a train is mechanically propelled, although there is only one motor to a train.

This "continued propulsion" is effected by means of a universal or cardan shaft running throughout the entire length of the train. From this shaft the power is transmitted to the center pair of wheels of each vehicle by means of an ordinary differential shaft and side driving chains. There is in the hub of each driving wheel a strong spiral spring drive through which the power is transmitted to the road wheels, thus ensuring very smooth starting even on the worst gradients and roughest of roads. The spring drive also takes up all undue shocks through transmission, saving much wear and tear throughout. Each follower chassis is mounted on six wheels, thus insuring a very light axle weight throughout the train, and consequently, no damage to road surface or bridges, as there are six bearing points on the ground, against four in most other methods of road transport.

The six wheels also reduce to a minimum all undue shocks and vibration due to bad roads. Experience shows that the distribution of driving power in the manner explained above makes it possible to use a light locomotor with an axle weight not above 4 tons when loaded with store spares, and consequently light driving wheels can take the place of the cumbersome wheels that have to be used on ordinary traction engines on account of the heavy axle weight and the amount of power transmitted through the one pair of wheels. Obviously the road train system gives much less heavy wear to roads and bridges than the old tractor method. Another advantage of this continued propulsion is, that, should one or two vehicles of a train get into trouble in soft or bad ground, and their driving wheels be unable to get an effective grip, but revolve idly, the driving wheels of the remaining vehicles, being on good ground are utilized to get the other vehicles out of the difficulty. The steering is unique, as each vehicle of a train is automatically steered, so that it follows in the exact track of the locomotor, like a train on rails, the driver having to steer the motor idly.

The motive power consists of an 80 horse-power, 6 cylinder motor of the Daimler Sleeve type and all trains are geared so that they can with ease negotiate, fully loaded, any hill up to a gradient of 1 in 5, or can traverse comparatively soft ground and tracks. The wagons each have a useful carrying capacity of 5 tons and the usual train will carry a total useful load of 20 tons. The speed of such a train on a fairly hard and level road is up to 10 miles per hour, although if a number of vehicles are used, the speed is decreased somewhat. The 6 cylinder 80 horse-power gasoline engine was designed for cooling in hot climates with a large steel radiator of honeycomb type, fitted with a powerful fan to draw air through the tubes and an additional water tank is also provided.

The drive from the engine is taken through an efficient coupling interposed to prevent any undue ware on the bearings. The gear-box provides four speeds forward and one reverse, and is so designed that the main driving shaft is continued right through to the rear of the locomotor. Immediately at the rear end of the gear-box this shaft is fitted with a worm-wheel, which drives a cross-shaft. At the ends of this cross-shaft, chain sprockets are provided, which convey the drive to the rear wheels by means of high quality roller chains. In this way part of the power from the engine is utilized in driving the locomotor and the remainder is conveyed through the long driving shaft, mentioned above, to the followers driving each of these in turn.

Between the locomotor and the first follower and also between each pair of followers, two very large universal joints are interposed, so that the drive may be transmitted when the train is proceeding round a sharp bend. In the center of each follower there is a gear-box, in which a pair of worm wheels transmit the drive to a cross-shaft, just as in the locomotor. From here a pair of chains lead to the central wheels of the follower, which is thus driven at the same speed as the locomotor. The main driving shaft continues through to the next follower.

In this way the power of the engine is divided among all the vehicles in the train. It should be mentioned that in each driving shaft a spring mechanism is fitted, so that any inequalities in the drive are effectively absorbed and, in addition, ease of starting is insured. The fact that the steering of the locomotor is communicated to each of the followers is almost as important as the mechanical propulsion of each vehicle, with the result that all the vehicles traverse a single path, forward and backward, however tortuous this may be. On the locomotor a hand wheel in front of the driver operates the usual worm and sector gearing of large dimensions, and the motion of the sector arm is transmitted to the front wheels by means of suitable links. These front or steering wheels are centrally pivoted, as are all steering wheels in the followers; this insures easy action, and prevents road shocks from being transmitted to the driver's arms and various parts of the mechanism throughout.

A self-contained steering mechanism is provided for each follower, which is automatically controlled by the vehicle immediately preceding it. The direction of the whole train is determined by the driver of the locomotor when going ahead, and, when going backward, by a man at the last wagon.

The steering bar is connected to a bracket mounted on the steering axle of the follower, so arranged that it can swing in a horizontal plane. The motion of this bracket is communicated to the two front steering wheels of the follower by means of a pair of rods which effect the steering on the usual Ackermann principle. The rear pair of wheels of the follower also steer, and these are connected to the front pair by means of two cross cables, so that the motion of the right hand front wheel is communicated to the left hand rear wheel and *vice versa*.

At the rear of the follower there is placed another horizontally swinging bracket and this is connected to the front bracket of the next follower by means of a steering rod, as between the locomotor and the first follower. In this way each vehicle is steered by the change in position of the vehicle immediately in front, and thus the steering is automatic. For steering backward, a hand tiller is placed in the rear bracket of the last follower and a man walks along, swinging this tiller to which ever side he wishes to go.

A road train on this system, having a useful carrying capacity of 20 tons, will have no heavier axle weight than 4 tons, whereas a lorrie carrying a useful load of 4 tons only, has an axle weight of 5 to 6 tons, and a traction engine capable of transporting a useful load of 20 tons under similar conditions, must have a maximum axle weight of from 4 to 5 times that of a train on this system.

A 4 ton motor is sufficient to work a train having a tare weight of 18 tons and carrying a useful load of 20 tons, that is a gross moving weight of 38 tons. The maximum tractive effort is provided as the driving wheels, worked by the transmission shaft, are distributed over the whole length of the train, and with full load, the steepest and longest hills are taken, also traversing comparatively soft roads and tracks with ease. Isolation of the motor from the remainder of the train results in absence of engine vibration and safety in case of fire or other accident.

The working costs are light per ton mile on account of the high average speed obtained and the large proportion of useful load to gross load carried.

A total run of 51.66 miles was made at an average speed, including traffic and railway crossing stops, of 8.65 miles per hour, and the gasoline consumption was very low. The number of train miles per gallon was 1.61, the net ton miles per gallon being 24.79 and the gross ton miles per gallon 47.33, the cost of operation being therefore very low.

Automatic Telephone Exchange Systems—II.*

A Survey of the Present State of the Art

By W. Aitken

Continued from Supplement No. 1880, page 22.

For an exchange from 100 to 1,000 lines a "selector" is fitted in addition to the connector. Fig. 7 shows the connections of a selector. This is very similar to the connector, but rather simpler as there are fewer relays, and after it has performed its work it joins the lines

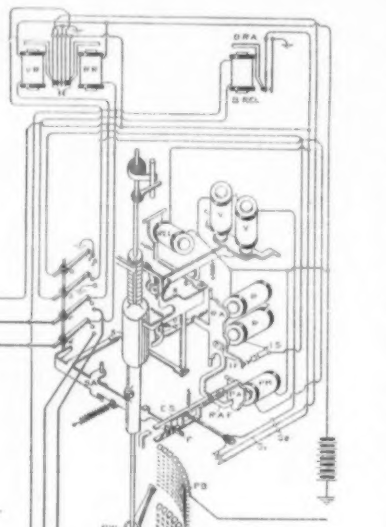


Fig. 7—Diagram of Selector Connections.

through and leaves no electromagnets attached. In its operation it differs from the connector in that after the shaft has been raised, owing to impulses from the dial, it rotates automatically until a junction line is found to a disengaged connector. This is brought about as follows: After the dial earths over the vertical line have raised the shaft, and the earth on the rotary line has actuated the private magnet *P.M.* which has moved the side switch to the second position, a local circuit is completed from earth through lever *a* of side switch through contact *I.S.*, through electromagnet *R* to battery and earth. The shaft is rotated one step and the armature *P.A.* is depressed by the extension *R.A.F.* If that line to a connector is idle (i.e., insulated) the *P.M.* will move the side switch to the third position when the line will be joined through. Should, however, the first connector line be engaged the armature *P.A.* will be held down, as a circuit is completed from earth on private bank (due to engaging selector) through *P.W.* coil of *B* relay, side switch lever *b* in second position and *P.M.* coil to battery and earth.

The electromagnet *R.I.* attracting its armature *R.A.* by finger *I.F.* opens the circuit at springs *I.S.* so that the armature is released. The armature is re-attracted, and this movement continues, rotating the shaft until the wipers engage with an idle line, when the private magnet armature *P.A.* is released and moves the side switch to the third position, when the lines are joined through. The selector is then entirely cut off from the lines, these being joined straight through.

A Keith "line switch," Fig. 8 (Fig. 9 shows the circuits) is now introduced between the subscriber's line and a selector. This is a most ingenious device to avoid the necessity for having an expensive selector associated with each line. Each circuit has its line and cut-off relay, like the manual exchange, and a release relay. These are arranged on each side of a vertical moving shaft in groups of 25, 12 on one side and 13 on the other. This shaft is pivoted and has a backward and forward movement. Each relay has a pivoted arm, or plunger, whose fan-shaped end has a notch which engages with the moving shaft normally. As the shaft moves it carries with it the plungers and causes them to move on their pivots, so that the point, which carries an ebonite roller, is moving in front of sets of springs. One bank or level of 10 groups of springs is in line with each plunger. The corresponding groups of springs in a unit are multipled together and connected to a selector. The unit is usually made up of four sections of 25, with which 10 selectors are associated, and the shaft is rocked by a master electromagnet. When the telephone is removed, and before the dial is touched, the line switch is operated automatically. The line or tripping relay has disengaged the plunger arm, and a spring drives the plunger into a group of springs, and also disengages it from the shaft, so that the subscriber's line has been extended to a selector, at the same time local circuits have been completed through the cut-off relay and the master switch electromagnet, so that the shaft is moved one step and the remaining 99 line relay plungers are opposite the No. 2 selector group of springs. The next call will engage No. 2, and the remaining 98 will then be carried opposite No. 3, the selector being thus always pre-selected. As the plungers become free the shaft picks them up on its return journey.

In the 2-wire system the mechanism is very similar to that of the 3-wire, but the electromagnets or relays controlling these are different. Advantage is taken of the slow-acting characteristic of relays having a mass of copper attached, so that two relays in series are actuated by the first completion of the circuit, but only one responds to the dial impulses.

The three relays of the line switch are now combined, in a most ingenious manner, into one having three armatures. The 2-wire circuits of a 1,000-line exchange connection are shown in Fig. 10. The master switch is shown controlled by a spring which is kept wound by a small motor, but the arrangement shown in Fig. 9 is still generally retained. In these circuits the system of registering calls when the wanted subscriber answers is shown, and it will be noticed that the connection circuits are considerably complicated thereby.

CIRCUITS OF TWO-WIRE SYSTEM.

When a receiver is removed to initiate a call:

1. A circuit is completed from earth 1, springs 2 and 3, line 4, receiver *R*, microphone *M*, line 5, springs 6

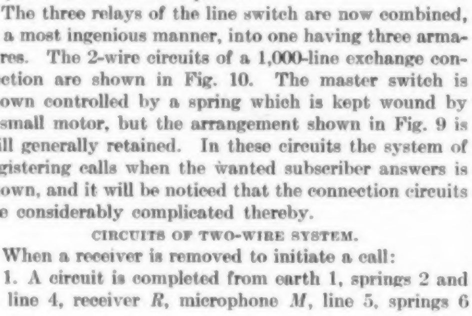


Fig. 8—Keith Line Switch (3-Wire).

and 7, winding 8, springs 9 and 10 of master switch relay to battery. Armature 11 is pulled up and

2. Completes a circuit from earth 1, springs 2 and 12, through windings 13 and 14 to battery, and armatures 15 and 16 are attracted.

3. Armature 15 causes springs 3 and 6 to break contact from springs 2 and 7 and cuts the winding 8 from line. (The armature 11 is, however, momentarily retained by winding 14 until another circuit is completed, when armature 16 short circuits winding 14 by contact 17 and 18). Armature 16 carries the plunger 20, which normally engages with the moving vertical bar. When armature 16 is attracted, therefore, the plunger 20 is forced forward until the insulated disk, passing between the springs in the bank, causes them to make the contacts shown at 21.

4. Line 4 is then extended by contacts *d* of bank springs 21 and by contact *a* of side switch 25, through one winding of selector line relay 26 to earth. Line 5 is extended through meter winding 27, contact *a* of bank springs 21, through contact *a* of side switch 22, through other winding of line relay 26 to battery, and the line relay is energized.

5. This in turn closes the circuit through the guarding relay 27, which energizing

6. Completes a circuit from earth 28, through upper contact of relay 27, contact *b* of bank springs 21, winding 29 of line switch magnet to battery, and this circuit maintains the line switch energized after winding 14 has been short-circuited.

7. Relay 27 also completes a circuit by line 28 through contact *b*, of bank springs 21, through meter winding 30, contact 31, spring 17, and contact 18 of line switch to battery. As current is then through both windings in opposite directions the meter is not actuated.

8. Relay 27 also puts earth on the wire 28 to the private bank to engage the line.

9. When the plunger 20 enters the group of springs 21, a circuit is also completed from earth by the contact *c*, through the master switch bank contact 32, by bridge 33 to common connector 34, relay winding 35 to battery. All line plungers are, therefore, rotated to the next disengaged contact or junction by the relay 35 attracting its armature and allowing a spring (motor controlled) to revolve the shaft. Battery is also cut off all lines at springs 9 and 10, so that no call can be made while the shaft is rotating.

10. By the removal of the receiver only a subscriber's line has, therefore, been extended to a first selector by a junction line pre-selected; the line switch has been cut off the line circuit and is retained operated in a local circuit; one coil of the meter remains (for the present) in circuit in one wire; the calling line has had an engaging current connected to the private bank; the master switch has carried all the line switches of a group opposite the next junction to a first selector. The circuit is now ready for the dial impulses.

11. Suppose the number wanted to be 734. With the finger in hole 7 the dial is revolved to the stop and the circuit at the instrument is opened 7 times. The selector line relay 26 is de-energized momentarily 7 times. The release relay 27 is slow acting and does not de-energize.

12. Relay 26, therefore, completes a circuit 7 times from earth on middle spring, under contact, through lower back contact on relay 27, line 37, through winding of private magnet relay 37 (which is slow acting and, therefore, remains energized after the first impulse) through winding of vertical magnet 38, through side switch 23 by contact *a* to battery. The vertical shaft therefore lifts the wipers to the seventh bank level.

13. Private magnet relay 37 when energized, by its springs, completes a circuit through the private magnet 41. The *P.M.* relay 37 de-energizes after the seventh impulse, in turn de-energizes the *P.M.* 41, and allows the side switches to pass to the second position, when

14. Another circuit is completed from earth 36, contact springs and winding of rotary magnet 39, through winding of guarding relay 40, through side switch 23 by contact *b* to battery. The wiper shaft is, therefore, rotated one step, and the wipers come to rest if that connector line is free. The rotary magnet 39 closes mechanically the armature of the private magnet 41 and also opens the circuit as shown at 39 by separating the springs. The armature of 39, therefore, falls back and the armature of the private magnet 41 also, and allows the side switches to pass to the third position.

15. If, however, the first connector circuit on that level is engaged, a circuit will be completed from earth through *b* wiper line 24, through side switch 24 by contact *b*, through *P.M.* 41 to battery. The armature of *P.M.* 41 therefore remains attracted. The armature of the rotary magnet 39 is re-attracted and continues

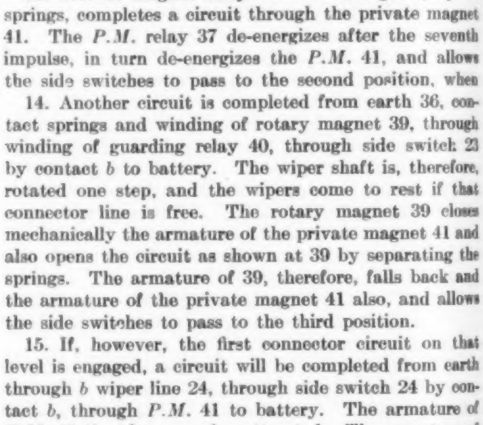


Fig. 9—Two Adjacent Line Switches, with Graphical Representation of Master Switch.

vibrating, at the same time moving the wiper *b* from contact to contact until a free line is obtained, when the *P.M.* 41 armature falls back and allows the side switch to pass to the third or *c* position.

16. The calling subscribers line (wires 4 and 5) are then connected to the selector wipers *a* and *c*; all selector electromagnets are cut off the line circuit, and the appa-

*Paper read before the Institution of Electrical Engineers, London, England.

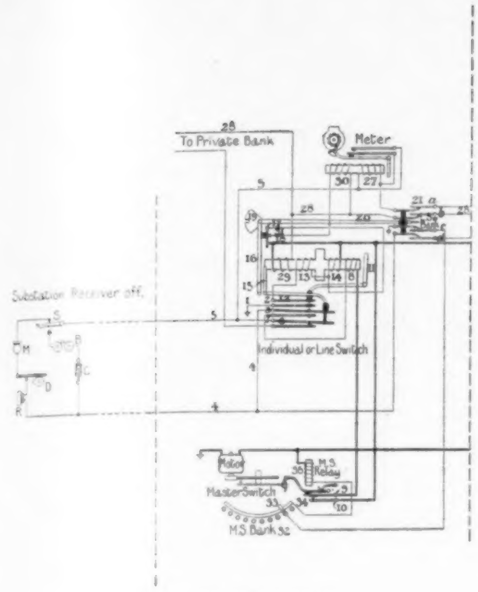


Fig. 10 (First Part).

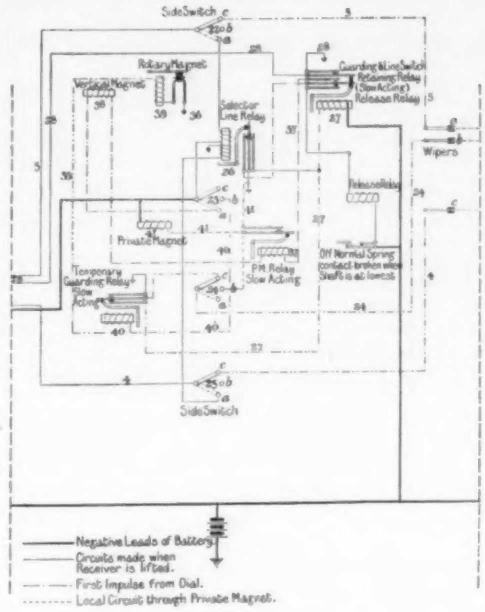


Fig. 10 (Second Part).

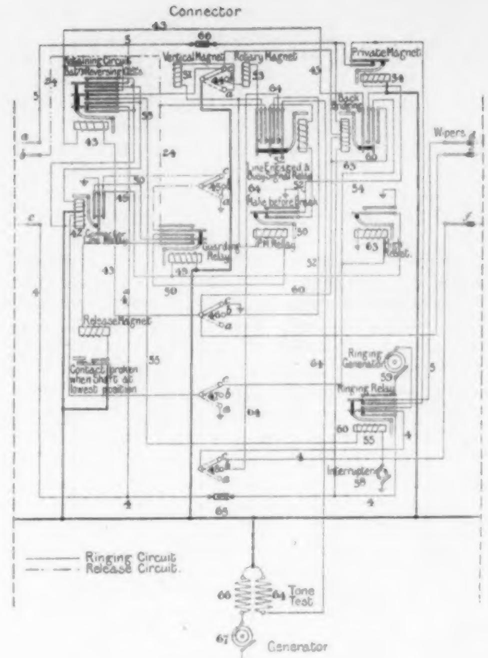


Fig. 10 (Third Part).

DIAGRAM OF 2-WIRE SYSTEM, 1,000 LINE EXCHANGE.

ratus is maintained in the through position by the wiper *b* completing a circuit from earth through wire 24, side switch 24 by contact *c*, under contact of relay 40, line 27, through winding of release relay 27 to battery.

17. When the selector wipers *a* and *c* make contact with the line tabs on the bank, the wires 5 and 4 are extended through the two windings of relay 42 to battery and earth, and this relay is immediately energized as the circuit is completed through the calling instrument. The wire 4 is extended by line switch bank 21, contact *d*, side switch 25 in *c* position, wiper *c*, line 4 and 4*a* bottom contact of relay 43, lower winding of relay 42 to side switch 47 by contact *a* to earth. The wire 5 by line switch bank 21, contact *a*, side switch 22 in *c* position to wiper *a*, by upper under contact of relay 43 to upper winding of relay 42 to battery.

18. Relay 42, when energized, completes a circuit from earth by back contact, through winding of relay 49 to battery.

19. Relay 49 completes the retaining circuit (relay 27) to earth from wiper *b* of selector, through upper back contact of relay 49 to side switch 45 by contact *a* to earth. Relay 49 is slow acting and does not de-energize when impulses are sent through relay 42.

20. No. 734 is being called, and so far the seven impulses have only been sent. The finger is now placed over figure 3 and the dial revolved, and the circuit at the instrument is opened 3 times, and the relay 42 pulsates 3 times.

21. A circuit is completed 3 times from earth by under contact of relay 42, back contact of lower group of springs relay 49, line 50, through winding of *P.M.* relay 50, winding of vertical magnet 51, side switch 44 by contact *a* to battery. The vertical magnet, therefore, lifts the shaft with the wipers to the third bank level.

22. At the same time *P.M.* relay 50 has been energized and completed a circuit from earth by back contact of relay 50, through winding of *P. M.* 54 to battery, and *P.M.* has been actuated and has opened the line circuit.

23. Relay 42 remains energized and the circuit of the private magnet relay 50 is, therefore, broken; the private magnet 54 circuit is likewise broken, and it returns to normal, allowing the side switches to pass to the second position.

24. The finger is then placed in the hole over the figure 4 (the last figure of the number 734) and the dial revolved. Relay 42 is again actuated 4 times, completing a circuit 4 times from earth, by back contact of relay 42, back contact of lower group of springs 49, winding 50 of private magnet, outside under contact of relay 52, rotary magnet 53, side switch 44 by contact *b* to battery. The rotary magnet 53, therefore, moves the wipers to the fourth group of springs of the connector. *P.M.* relay 50 again de-energizes, and if the line wanted is idle, the private magnet 54 is also de-energized and allows the side switch to pass to the third position.

25. The wire 4 of the calling line is then joined through condenser 65, under contact of relay 55, side switch 48 by contact *c*, to wiper *f* and one side of the called line; and wire 5 of the calling line by condenser 66, the contact of *P.M.* 54, and the upper under contact of relay 55 to the wiper *d* to the other wire of the called line, and a guarding potential or engaged test is placed on the line called at wiper *e*, from earth at side switch 46 by contact *c*, wiper *e*, winding 56 of line switch of called line to battery.

26. The line switch is energized, the armature 57 being attracted, and the circuit completed from wiper *d* by line 62 to the telephone, and the line switch coils cut off from the line called.

27. The side switch 44 in the third position completes

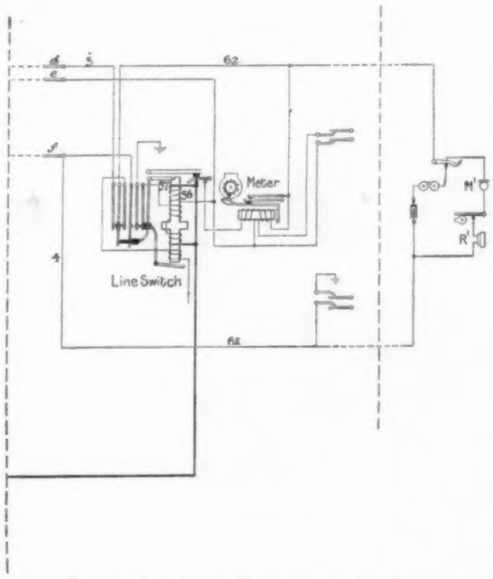


Fig. 10 (Fourth Part)—Diagram of 2-Wire System, 1,000 Line Exchange.

a circuit from earth through interrupter 58, ringing relay winding 55, line 55, through central under contact of relay 43, through side switch 44 by contact *c* to battery and relay 55 is energized.

28. Relay 55 cuts off the calling line and intermittently connects the called line to the ringing generator 59.

29. When the receiver is lifted to answer, a circuit is completed from earth, through side switch 46, by contact *c*, lower winding of relay 60, lower under contact of relay 55, side switch 48 by contact *c*, to wiper *f*, line 61, receiver R^1 and microphone M^1, switch hook upper contact, line 62, outer contact of line switch, wiper *d*, outer under contact of relay 55, contact of relay 54, to upper winding of relay 60, side switch 44 by contact *c* to battery. Relay 60 is, therefore, connected in bridge across the called line and is energized, and current is fed through the windings for the microphone M^1.

30. Relay 60 completes a circuit from earth, through side switch 46 by contact *c*, relay winding 43, line 43, left-hand contact of relay 60 to battery. Relay 43 is energized, and a retaining circuit is then completed from winding 43, through middle upper contact of relay 43, through side switch 44 by contact *c* to battery.

31. Another circuit is completed by relay 60. from earth by side switch 46 by contact *c*, line 60, line 63, through right-hand back contact of relay 60, to side switch 47 by contact *c*, to lower winding of relay 42, so that the resistance of relay winding 63 is cut out of circuit.

32. Relay 43 when actuated as described in (29) reverses the connections between the called line and relay 42, the circuit now being from earth at side switch 46 by contact *c*, back contact of relay 60, side switch 47 by contact *c*, lower winding of relay 42, outer upper contact of relay 43, to the *a* wiper of the selector, line 5, through calling instrument, back by line 4 and *c* wiper of selector, lower upper contact of relay 43, to upper winding of relay 42, to battery.

33. It will be remembered that current is through both windings 30 and 27 of the meter, but in such directions that they neutralize. The reversal of the current, by relay 43, now causes this to actuate and register. The meter contact closing short circuits the winding 27 and the meter is retained in the energized position by the local winding 30. No action of either of the subscribers, therefore, can cause it to operate more than once.

34. Relay 63 is used in semi-automatic systems. Being first connected in series with the lower winding of relay 42 and then shunted by relay 60, additional current is sent to line, which may be utilized to operate a supervisory signal on a cord circuit. Being of considerable resistance, and to prevent trouble should relay 42 fail to act, the earth on back contact keeps relay 49 actuated.

35. When conversation is finished and the circuit opened by replacing the calling subscriber's receiver,

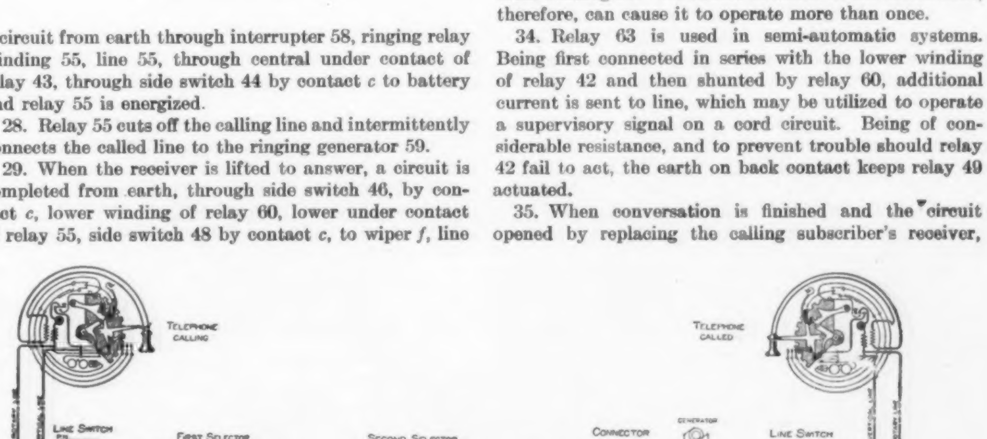


Fig. 11—Connections of 10,000 Line Exchange.

relay 42 is de-energized. This opens the circuit of relay 49 of the connector and relay 27 of the selector, and both complete a circuit through the associated release magnet. The former from earth and under contact of relay 42, under contact of relay 49, through release magnet winding and contact to battery. The latter from earth and under contact of relay 26 to under contact of relay 27, through release magnet winding and contact to battery. The release magnets attract the dogs and thereby release the wiper shafts which are revolved by the controlling springs, until they fall by gravity to the normal position. In this position the release magnet contacts are open and cut off the battery. All circuits are broken and apparatus returned to normal position for calling.

36. Should the line called for be engaged there will be a guarding potential on the private bank of the connector. This circuit in the connection just described, is from earth at side switch 46 at contact *c*, to wiper *e* through winding 56 of individual switch, to battery.

37. Another connector wiper now making connection with the same line by a multipled bank contact, will complete a circuit from earth by side switch 46 (contact *c*) wiper and bank contact *e* of the engaged line, contact bank and wiper *e*, side switch 46 by contact *b*, middle under contact and winding of relay 52, under contact of *P.M.* relay 50 (lines 52 and 54) private magnet winding 54 to battery, all on connector of the line attempting to call the circuit already engaged.

38. With the result that the private magnet 54 opens the circuit of the calling line, the other wire from wiper *f* is open at the side switch 48 contact *c*.

39. Relay 52 energizing also closes its middle outer contact so that the circuit of relays 54 and 52 is completed by upper back contact of relay 49 to side switch 45 by contact *b* to earth (to further safeguard the line attempted to be called).

40. The contact nearest the winding of relay 52 is also closed, and a circuit is completed from the secondary circuit of the busy signal machine 64, line 64, make contact of relay 52, side switch 48, by contact *b*, bottom under contact of relay 55, through condenser 65 over wire 4 and through calling instrument, and back by wire 5 to outer under contact of relay 43, upper winding of relay 42, and by common battery lead to the busy signal secondary winding.

41. The busy machine primary circuit 66 is from earth through interrupter 67, winding 66, through battery to earth.

42. When the receiver is replaced after the busy signal is heard all apparatus is returned to the normal condition.

43. If the line with which connection is desired originated the call, the engaging circuit will be from the selector earth 28, upper outer contact of relay 27, contact *a* of line switch bank, winding 29 of line switch to battery, with a branch to the private bank contact.

When an exchange is over 1,000 and up to 10,000 lines, a second selector is added—Fig. 11 (3-wire system). When a capacity of 100,000 lines is required, a third selector is used, and so on.

We will recapitulate the operation of a 1,000-line equipment. On an exchange of this size there will be 1,000 line switches (i.e., one per line) 100 first selectors, and 100 connectors. It is found in practice that a 10 per cent basis is ample for ordinary exchanges; very rarely are there more than 10 connections (or 20 telephones talking) per 100 lines.

After the receiver has been lifted, and before the dial has been revolved to the stop, the line switch has done its work and connected with an idle selector. If the number desired is 865 the caller will place a finger over the number 8 and revolve the dial to the stop. The

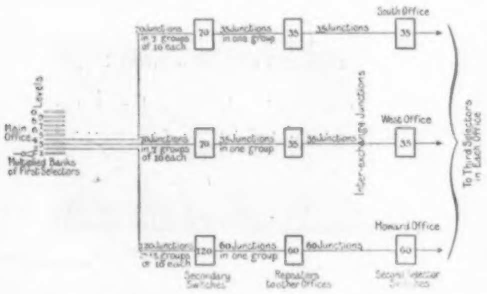


Fig. 13—Junction Lines, San Francisco.

selector will step up to the eighth level of contacts and come to rest on the first set of contacts if these are disengaged; if, however, that line to a connector is already engaged, the shaft will continue to rotate automatically until an idle connector line is found. The finger will then be placed over the figure 6, and the dial revolved to the stop, when the connector will step up to the sixth level, but will not make contact with any line. The finger will then be placed over the figure 5, and the dial revolved to the stop, when the shaft will rotate until the fifth group of springs on the sixth level is reached.

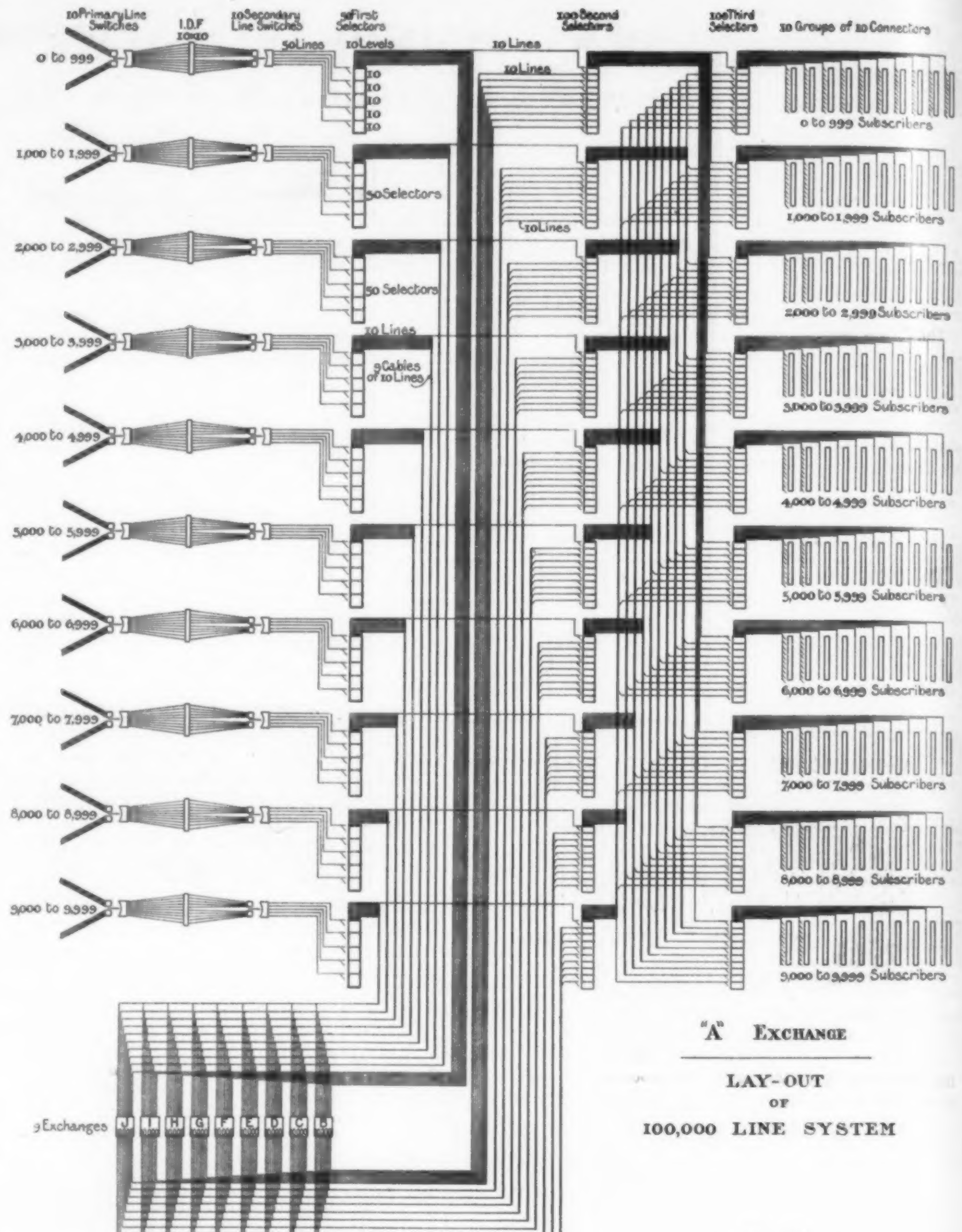


Fig. 12.

When stations below 100 in an exchange of 1,000 lines are called the number is preceded by *O* so that the sequence of operations may remain the same, or the two figure numbers will be omitted.

On 100,000-line systems, instead of using five figures to identify a line, four figures are used preceded by a letter as being easier to remember, and generally the letters indicate a different exchange, as the system is usually built up of ten exchanges, or, ten groups of exchanges, each having a capacity of 10,000 lines.

One level of the bank contacts on a first selector, therefore, will be associated with the local exchange, say Central, the second with North, the third with South, and so on. The line switch having automatically connected with a first selector the first movement of the dial will cause that selector to pick up a second selector in one of the groups of 10,000 (this second selector, like the first, may have the level connected with a local exchange and each of the other levels connected with sub-exchanges, or all the levels may be connected to different groups of 1,000 in the same exchange) and this in turn will pick up a third selector in a group of 1,000, which will pick up a connector and complete the connection as previously described.

It will thus be seen that there is no junction working in the sense of special or more complicated operating such as we usually associate with manual exchanges. The 10 per cent of lines between selectors may be reckoned as junctions, but the operating is uniform whether they are in the same building or connecting exchanges some miles apart. Fig. 12 shows the lay-out of a 100,000-line system.

It has been found in practice that 10 per cent of lines between first and second selectors in these large installations is unnecessarily high owing to the rapidity of service, and a "secondary line switch" has been introduced to reduce that number. Both line switches act automatically and are quite independent of any movement of the dial. This still further reduces the number of lines between exchanges.

In the diagram the 50 lines from a secondary line switch are shown connected to one group of first selectors for the sake of simplicity. It would be better to connect five lines to each group of first selectors.

To equalize the traffic on the first selectors an intermediate distributing board is introduced between the primary and secondary line switches.

By the introduction of secondary line switches any subscriber's line may use any first selector and any junction line is made available to any first selector.

Fig. 13 shows how junction lines between exchanges are made available to all subscribers. Mr. Arthur Bessey Smith points out that by increasing the number of junctions on a group of secondary line switches, the traffic that may be carried is greatly increased, e.g., if there are only 10 junctions in a group, only 225 busy hour calls or 22.5 calls per junction will be carried, if 20 junctions are in a group 575 busy hour calls or 28.75

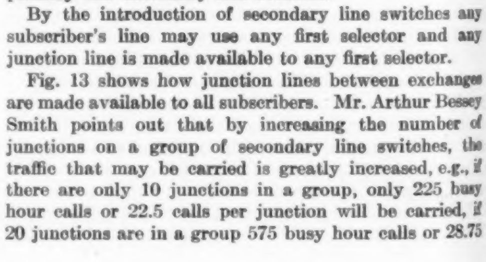


Fig. 14—Speaking Circuits over Junctions.

calls per junction, whereas if 100 junctions are in a group 4,000 busy hour calls or 40 per junction may be efficiently carried.

Great care has been taken in designing lines between exchanges to balance them, and as will be seen from Fig. 14 the simplified circuit is equal to that on any manual system. The circuits are divided for signalling purposes by condensers, and current for the microphones is supplied from a battery in the exchange at each end of the junction as on manual systems. The repeater is for repeating dial impulses only.

To be continued

A New Method of Chemical Analysis*

Identifying Substances Undetermining Their Molecular Weight in One Apparition

By Prof. Sir J. J. Thomson, F.R.S.

I HAVE had on several occasions the privilege of bringing before the members of the Royal Institution some of the results of the experiments on the positive rays on which I have been engaged for the last few years. I wish now to direct your attention to some applications of these to various chemical problems.

The first application I shall consider is the use of these rays to determine the nature of the gases present in a vacuum tube, to show how they can be used to make a chemical analysis of these gases—an analysis which, as we shall see, will enable us to determine, not merely whether an element, say, for example, oxygen, is present in the tube, but will tell us in what form it occurs, whether, for example, it is present in the atomic as well as the molecular condition, and whether there are allotropic modifications present, such as ozone, O_3, and other still more complex aggregations.

The method is as follows: the positive rays, after passing through a fine tube in the kathode, are exposed simultaneously to magnetic and electric forces, the magnetic field being arranged so as to produce a vertical deflection of the rays, while the electric field produces a horizontal deflection. Thus, if when neither electric nor magnetic fields are present, the rays strike a screen placed at right angles to their direction at a point O, they will, when both electric and magnetic forces are at work, strike it at a point P, where the length of the vertical line PN is equal to the deflection produced by the magnetic field, and the horizontal line ON to that produced by the electric field.

We know from the theory of the action of electric and magnetic fields on moving electrified particles that

$$PN = A\frac{e}{v} \qquad ON = B\frac{e}{mv^2}$$

where A and B are constants depending on the strength of the magnetic and electric fields and the geometrical data of the tube, e is the charge on the particle, m its mass, and v its velocity.

From these relations we see that

$$\frac{m}{e} = \frac{A^2}{B}\,\frac{ON}{PN^2}$$

When these rays strike against a photographic plate, they affect the plate at the point against which they strike, and thus when the plate is developed we have a permanent record of the deflections of the rays. The values of A and B can be determined accurately by the methods I have given elsewhere, and hence if we measure on the photographs the values of ON and PN, we can determine the value of m/e. If we wish to compare the values of m/e for two different rays, it is not necessary to determine A and B; all we have to do is to measure the values of ON and PN, and thus the photograph alone gives us the means of comparing the value of m/e.

Since for the same type of carrier m/e is constant, whatever may be the velocity, $\frac{PN}{NO}$ is constant, and therefore the locus of P, i. e., the curve traced on the photographic plate by this carrier, is a parabola. The reason we get a curve instead of a point is that the rays are not all moving with the same velocity, and the slower ones suffer greater deflection than the quicker ones. Each type of carrier produces its own line on the plate, and there are as many curves on the plates as there are kinds of carriers; from an inspection of the plates we can find, not merely the number of kinds of carriers, but from the dimensions of the curves we can at once

Fig. 1.—Diagram of the electric force ON and the magnetic force NP on a charge at O, with resultant OP

determine the atomic weight of the carrier, and thus determine its nature. This is one of the great advantages of this method. To illustrate this advantage, let us compare the method with that of spectrum analysis. If the spectroscopist observes a line unknown to him in the spectrum of a discharge tube, the most he can deduce without further investigation is that there is some unknown substance present in the tube; and even this would be doubtful, as the new line might be due to some alteration in the conditions of the discharge. But if we observe a new curve in the positive-ray spectrum, all we have to do is to measure the curve, and then we know the atomic weight of the substance which produced it. To take an example, I have photographed the positive-ray spectrum for nitrogen prepared from the atmosphere and that for nitrogen prepared from some nitrogenous compounds, and have found that the former contains a line[1] which is not in the latter, and that the value of m/e for this line is 40 times that for the atom of hydrogen. We thus know that atmospheric nitrogen contains an element of atomic weight 40, which is not present in chemical nitrogen—this element is, of course, argon. We might by ordinary spectrum analysis have found lines in the spectrum of atmospheric nitrogen which are not in the spectrum of chemical nitrogen, and might thus have suspected the presence of another element; but spectrum analysis could not tell us anything about the nature of this element, whereas the positive-ray spectrum at once gives us its atomic weight.

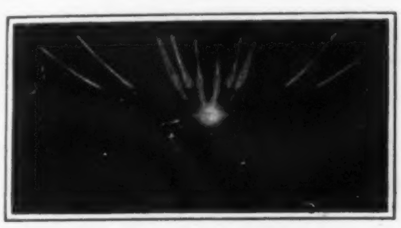


Fig. 2—Atmospheric Nitrogen.

Fig. 3—Carbon Monoxide.

Fig. 4—Carbon Dioxide.

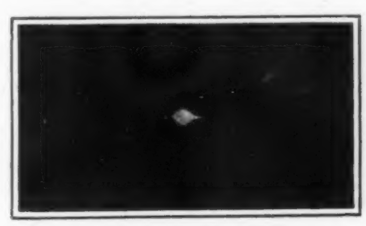


Fig. 5—Marsh Gas.

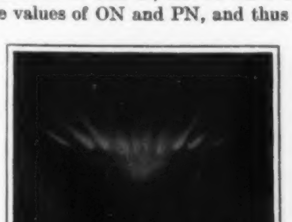


Fig. 6—Chloroform.

Fig. 7—Silicon-methane.

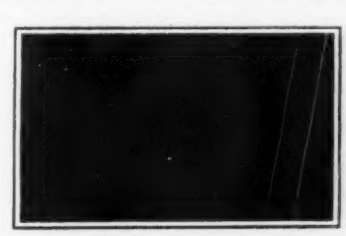


Fig. 8—Positive Ray Spectrum of Air.

The positive-ray method is even more delicate than that of spectrum analysis, for by it we can detect the presence of quantities of a foreign gas too minute to produce any indication in the spectroscope. I have, for example, often been able to detect the presence of helium by this method when no indication of its presence could be detected by a spectroscope.

Again, when a line in the positive-ray spectrum can be seen, the atomic weight of the carrier which produces it can be determined with great accuracy. Though the method is only a few months old, it is even now sufficiently developed to determine with an accuracy of 1 per cent the atomic weight of a gaseous substance, without requiring more than 1/100 milligramme of the substance. Another very important advantage of this method is that it is not dependent upon the purity of the material; if the material is impure, the impurities merely appear as additional lines in the spectrum, and do not affect the parabola due to the substance under examination, and therefore produce no error in the determination of the atomic weight. The method would seem to be peculiarly suitable for the determination of the atomic weights, not merely of the emanation from radio-active substances, but also those of the products into which they disintegrate

The rays, too, are registered within less than a millionth of a second after their formation, so that when chemical combination or decomposition is occurring in the tube the method may disclose the existence of intermediate forms which have only a transient existence, as well as of the final product, and may thus enable us to gain a clearer insight into the process of chemical combination.

I will now show a few slides prepared from the photographs we have taken of the positive-ray spectra. The first (Fig. 2) is that of nitrogen prepared from air; the measurements of the photograph showed that the atomic weights of the carrier producing these curves were as follows:

Positive		*Negative*	
1	$H+$	1	$H-$
1.99	H_2+	11.20	$C-$
6.80	$N++$	15.2	$O-$
11.40	$C+$	..	
13.95	N	..	
28.1	N_2+	..	
39	Arg+	..	
100	$Hg++$	..	
198	$Hg+$	..	

The symbol H+ denotes that the carrier is an atom of hydrogen with one charge; H_2+ that it is a molecule of hydrogen with one charge; N++ that it is an atom of nitrogen with two charges; and so on.

With nitrogen from NH_4NO_3 the lines were as follows (the magnetic force was so large that some of the lines corresponding to the lighter particles were thrown off the plate):

6.1	$C++$	44.2	CO_2+
7.02	$N++$	65.5	$Hg+++$?
12.08	$C+$	100	$Hg++$
14.01	$N+$	204	$Hg+$
27.9	N_2+		

The next photograph (Fig. 3) is the positive-ray spectrum for CO, and again the magnetic field is so great that the lighter carriers do not appear.

From the measurement of the lines we find that the atomic weight of the carrier is

* Discourse delivered at the Royal Institution.

[1] As a matter of fact, there is a second, very faint line for which m/e is about twenty times that for the atom of hydrogen. This is probably due to an atom of argon with two electric charges.

Positive	*Negative*
6.00 C + +	12 C −
6.95 N + +	16 O +
7.95 O + +	..
12.02 C +	..
13.9 N +	..
15.95 O +	..
28.05 CO +	..
43 CO_2 +	..
69.5 Hg + + +(?) very faint	..
100 Hg + +	..
202 Hg +	..

The spectrum for CO_2 is represented in Fig. 4; the atomic weights are:

5.98 C + +	43.9 CO_2 +
8.00 O + +	62.5 Hg + + +(?) very faint
12.00 C +	99.6 Hg + +
16.00 O +	200.0 Hg +
28.02 CO +	

The spectrum of CH^4, of which a small region with five lines close together is shown in Fig. 5, is interesting, because the measurement of these lines shows that their atomic weights are 12, 13, 14, and 15, 16, and thus that we have here C, CH, CH_2, CH_3, CH_4. If I am not mistaken, this is the first occasion when the atoms CH, CH_2, CH_3, have been observed in a free state.

The spectrum of the analogous compound chloroform, $CHCl_3$, is represented in Fig. 6. The atomic weights represented in this are:

1 H +	18.5 Cl + +
1.5 (?)	27.7 CO +
2 H_2 +	36 Cl +
3. (?)	46.5 CCl +
6 C + +	63 (?) faint
8 O + +	81 CCl_2
11.9 C +	102 Hg + +
13.7 N +	201 Hg +
16 O +	

The carriers with atomic weights 1.5 and 3 have not been identified. They are of frequent occurrence. I have here two slides, one of SiH_4 (Fig. 7) and the other of the residual gas in the tube, in which they are well marked, though at their best they are only faint lines. In Fig. 8 we have the positive ray spectrum of air, taken under conditions which produce very narrow lines, which can be accurately measured.

Let us now consider some of the results brought to light by these photographs. In the first place, they show that a gas through which an electric discharge is passing is a much more complex thing than a collection of molecules all equal to each other. Even an elementary gas becomes in these circumstances a mixture of a great many different substances. Thus, to take oxygen as an example, the photographs show that when a current of electricity passes through it, we may have present simultaneously oxygen in the following states:

1. Ordinary molecular oxygen, O_2.
2. Neutral atoms of oxygen, O.
3. Atoms of oxygen with 1 positive charge, O +.
4. Atoms of oxygen with 2 positive charges, O + +
5. Atoms of oxygen with 1 negative charge, O −.
6. Molecules of oxygen with 1 positive charge, O_2 +.
7. Ozone with a positive charge, O_3 +.
8. O_6 with a positive charge, O_6.

And, in addition, there are free negative corpuscles. Thus in the elementary gas there are at least nine (the list has no claim to be exhaustive) separate substances present when the discharge passes through it. Each of these substances has almost certainly different properties, possibly a characteristic spectrum. If we took any other gas we should find that the same thing would be true: thus in hydrogen we have H, H_2, H +, H −, H_2 +, even if we do not ascribe to hydrogen the lines giving $m/e = 1.5$ or 3. In nitrogen we have N, N_2, N +, N + +, N_2 +, carbon occurs as C +, C + +, C −, chlorine as Cl, Cl_2, Cl +, Cl + +, and Cl −, mercury as Hg, Hg +, Hg + +, and probably as Hg + + +, as there is a very persistent line for which m/e is about 66

Thus, whenever the electric current passes through a gas, and probably whenever a gas is ionized, the gas becomes a mixture of many different substances. We can thus readily understand why in the spectra of many elements many of the lines may be grouped together so as to form different series—the principal series, the first co-ordinate series, and so on—and the spectrum of the discharge tube regarded as the superposition of a number of different spectra the relative intensities of which may be subject to very great variations. This, indeed, is just what would happen if some of all of the substances which are present when the gas is in the ionized state gave rise to different spectra.

Another feature which I think is of great interest from the point of view of the theory of chemical combination is the occurrence of particles with negative charges. Let us consider for a moment how these are formed. They are formed after the particles have passed through the kathode; the path between the kathode and the photographic plate contains abundance of corpuscles produced by the ionization of the gas: a neutral particle, after passing through the kathode, picks up a negative corpuscle, and so becomes negatively charged. For this to occur, the attraction between the corpuscle and the neutral particle must be exceedingly strong, for it is not a question of a particle at rest attracting to itself a negatively electrified corpuscle sauntering about in its neighborhood. In our case the neutral particle is rushing past the corpuscle with a velocity of the order of 10^8 centimeters per second. In order that the particle may in these circumstances be able to drag the corpuscle along with it, the attraction between the two must be so great that to move a corpuscle against this attraction from the surface of the particle away to an infinite distance must require an amount of work of the same order as that required to communicate to the corpuscle a velocity of 10^8 centimeters per second; this is equal to the work required to move the atomic charge against a potential difference of about 3 volts, and is therefore comparable with the work required to dissociate some of the most stable chemical compounds.

The fact, then, that some particles get negatively charged shows that in the neutral state these particles have an exceedingly strong affinity for a negatively electrified particle, while the absence of a particular particle from the negative side shows that its affinity is much less, but does not imply that it vanishes altogether. From what we have said, it should follow that the more slowly the neutral particles are moving relatively to the corpuscles, the more easily will the negatively electrified systems be formed. This is confirmed in a very striking way by our experiments, for when the discharge is passing very easily through the tube, and the velocity of the neutral particles is relatively small, the number of negatively electrified particles is very much increased; indeed, in some cases the brightness of the part of the photograph corresponding to the negative particles is as great as that corresponding to the positive, whereas when the discharge is passing with great difficulty, and the velocity of the neutral particles is very high, the negative part is very faint compared with the positive.

The particles which have been observed on the negative side are the hydrogen atom, the carbon atom, the oxygen atom, and the chlorine atom. The presence of oxygen and chlorine atoms might, perhaps, have been expected, as these are universally regarded as strong electro-negative elements, i. e., as elements which have a strong affinity for negative electricity. The presence of the hydrogen atom is more remarkable, for hydrogen is generally considered to be a strongly electro-positive element, yet on these photographs we find it more persistently on the negative side than any other particle: often when no other line on the negative side is strong enough to be detected, the line corresponding to the hydrogen atom is distinctly visible. This is all the more remarkable, because the hydrogen atom, being the lightest of all the particles, is moving with the greatest velocity relatively to the corpuscles, and therefore would, other circumstances being the same, be the least likely to capture them. The heavier the particle, the slower is its velocity, and the greater chance it has of capturing the corpuscles; the fact that heavy complicated particles are conspicuous by their absence on the negative side shows that the attraction of these for the corpuscles must be exceedingly small compared with that exerted by a neutral atom of hydrogen. It will be seen that the atom of carbon, also regarded as an electro-positive element, is also conspicuous on the negative side.

On looking at the list of the particles which occur on the negative side, we are struck by the fact that they are all atoms: there is not a molecule among them. Thus, although the curve corresponding to the negatively electrified hydrogen atom occurs on every plate, there is not a single plate which shows a trace of a curve corresponding to a negatively electrified hydrogen molecule, although that corresponding to the positively electrified molecule is always present, and on some of the plates is stronger than that due to the positive hydrogen atom. Again, on some plates the positive oxygen molecule shows stronger than the oxygen atom, but on the negative side only the atom is visible.

Thus neutral atoms, but not neutral molecules, can exert on the negative corpuscles those enormous attractions which, under the conditions of these experiments, are required to bind the corpuscles to these rapidly moving particles. We may compare this result with the properties ascribed by chemists to bodies when in the nascent condition, i. e., when they have only recently been liberated from chemical combination, and when they are likely to be partly in the atomic state, for atoms, as we have seen, exert forces on electric charges in their neighborhood vastly greater than those exerted by molecules.

We may compare the forces exerted by a neutral atom on the corpuscles with those exerted by an unelectrified piece of metal on a charged body in its neighborhood. In consequence of electrostatic induction, the charge and the metal will attract each other. This attraction is dependent on the electricity in the metal being able to move under the electric forces exerted by the charge, and to rearrange itself in such a way that if the charge is positive, the negative electricity in the metal moves to the part of the metal nearest to the charge, while the positive electricity moves to the part remote from the charge. The force between the metal and the charge depends on the freedom of the electricity to move about in the metal under the action of the electric field. If the metal is replaced by a substance of high specific inductive capacity, like sulphur, in which the electricity has an appreciable amount of freedom, though not so great as in a metal, the attraction, though still appreciable, is very much less than it was with the metal. A very simple experiment will illustrate this point. I have on this cardboard disk, which is suspended from a long string, a number of magnets such as are used for compasses; if I mount the magnets on pivots, so that they are free to turn round, the system of magnets is strongly attracted when another magnet is brought near it; if, however, I take the magnets off their pivots, so that they are no longer free to turn, the magnet exerts very little attraction upon them.

A view of chemical combination which I gave some time ago in *The Philosophical Magazine*, and also in my "Corpuscular Theory of Matter," suggests that there is a very close analogy between the causes at work in the experiment we have just made and those which produce the difference between the behavior of atoms and molecules. On that theory the atom was supposed to consist of a large number of corpuscles arranged inside a sphere of positive electricity, the corpuscles arranging themselves so as to be in equilibrium under their mutual repulsion and the attraction of the positive electricity. The configuration depends on the number of corpuscles, and the stiffness and stability of the system also change as the number changes. For some particular numbers of corpuscles the system is very rigid, and any movement of the corpuscles would be strongly resisted; since the movement of electricity inside the atom is brought about by the movement of the corpuscles, the electricity could only move with great difficulty inside these atoms, and they would therefore not be able to exert more than feeble forces on electrical charges outside the atom: they would therefore not enter readily into combination with other atoms. We may ascribe such a constitution as this to the atoms of the inert gases, helium, argon, and neon. A system with one, two, or three more corpuscles than the system we have just described would not be nearly so stable, and there would be a tendency to discard the extra corpuscles from the atom so that it might return to the more stable form. We may roughly picture to ourselves the atom with one extra corpuscle as consisting of a number of fixed corpuscles plus one which is free to move about; the freedom of this corpuscle would enable the electricity in the atom to move about, and would endow the atom with the property of attracting any electrical charges which might be near it. If there were two corpuscles in the atom more than the number required for the most stable form, we can picture the atom as having two corpuscles free and the rest fixed. Similarly, if we had more than two extra corpuscles. Thus we may regard the atom as possessing 0, 1, 2, 3 corpuscles which are able to move about with more or less facility, and the free corpuscles will give to the atom the power of exerting attractions on electrical charges to an extent which depends on both the number of corpuscles and the freedom with which they can move about. On the theory to which I have alluded, the number of these "free" corpuscles determines the valency of the atom.

Now let us suppose that two such atoms come into such close connection that the corpuscles in the one exert considerable forces on those in the other. The system consisting of the two atoms will rearrange itself so as to get into a more stable form, if necessary, corpuscles passing from one atom to the other to enable it to do so. The greater stability, however, implies a loss of mobility; the free corpuscles have become parts of a more stable system, and have therefore lost to a greater or less extent their mobility. But with the mobility of the corpuscles goes their power of exerting forces on electrical charges, and thus the combination of the atoms diminishes to a great extent the attraction they exert outside them. Speaking generally, we may say that on this view the combination of atoms to form molecules, either of compounds or elements, fixes corpuscles which were previously mobile and converts the atoms from conductors of electricity into insulators with a small specific inductive capacity.

I have brought these illustrations before you with the object of showing that we have now methods which are capable of dealing with much smaller quantities of matter than the methods now used by chemists, methods which are capable of detecting transient phases in the processes of chemical combination, and I am hopeful may be of service in throwing light on one of the most interesting and mysterious problems in either physics or chemistry—the nature of chemical combination.

House Numbers On Curb

AN experiment which was tried out thoroughly by the city of Pasadena, Cal., and has been pronounced a success, is that of placing the house numbers at the curb in front of each residence, conspicuous black numerals being placed on a white rectangle. The names of the streets also are painted on the curb at street intersections.—*Municipal Engineer.*

Gas Engine Piston Rings*

A Page From an Engineer's Notebook

By S. H. Sweet

DESIGNERS of gas engines usually have certain forms of construction which they use in preference to others, but it is a good idea to know of the different forms in use, how they stand up, their good and bad points, the cost of manufacture, and how easily assembled

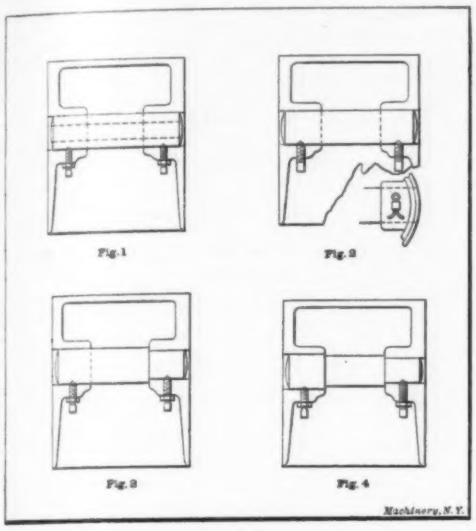


Fig. 1.—Straight pin held by nut-locked set-screws. Fig. 2.—Same pin with set-screws locked by cotters. Fig. 3.—Two-stepped pin. Fig. 4.—Three-stepped pin.

and disassembled. Herewith are shown a number of wrist-pins for gas engine pistons, taken from the writer's note-book, and some comments are made on the different designs.

The wrist-pin shown in Fig. 1 is a straight pin which is held from end movement and from turning by set-screws with lock-nuts. The pins are spotted for the point of the set-screw, so that the latter will not form a burr which might cause trouble in removing the pin. The pins are made either solid or hollow as desired. When made hollow, a few holes drilled through the center connecting with an oil groove, form a good means of lubricating the wrist-pin bearing at the piston end of the connecting-rod. The one shown in the illustration is probably the simplest and least expensive construction.

Fig. 2 shows the same construction as Fig. 1, with the exception that the set-screws are locked by cotter-pins instead of lock-nuts; the cotter-pins strike the wall of the piston and prevent the screw from turning. In some cases one set-screw is used instead of two. With a straight pin it is necessary to drive it in its full length, unless two different sizes of reamers are used, making one end a driving fit, and the other a sliding or running fit. However, if the wear on the central portion of the wrist-pin bearing forms a burr, it makes the removal of the pin difficult.

Fig. 3 shows a pin turned smaller on one end and held in the same way as that in Fig. 1. This pin can move in only one direction and only one set-screw is necessary. This construction costs more than the first, but the pin is more easily removed.

A three-step pin is shown in Fig. 4, and is held in the same manner as the one in Fig. 1. It is very easily assembled and removed, and it is only necessary to drive it the length of one of the piston bosses. While it is an expensive construction on account of the necessity for turning three sizes on a pin and requiring two sizes of reamers in the piston, this is compensated for by the fact that it can be turned down when worn without disturbing the ends which fit the piston.

In Fig. 5 is shown a hollow, straight pin kept from turning by a screw reduced on one end. The reduced part fits into a hole drilled in the wrist pin and the inner

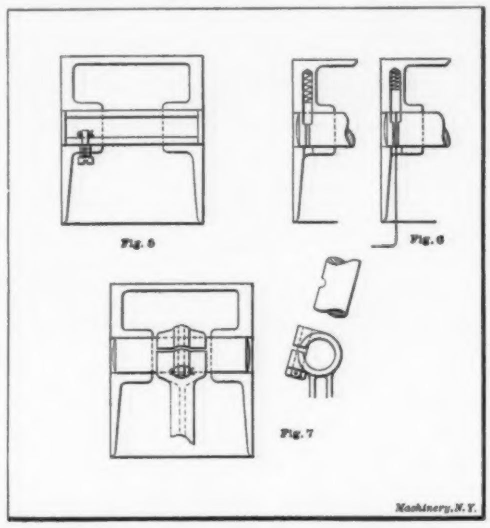


Fig. 5.—Hollow pin held by Projecting reduced end of set-screw. Fig. 6.—Spring-pin method of holding wrist-pin. Fig. 7.—Pin held by screw in end of connecting-rod.

end is drilled to receive a cotter-pin to prevent it from backing out.

A pin held by a small plunger or spring-pin is represented in Fig. 6, where the construction may be readily understood. When assemblying, the spring and plunger are put in place and the wrist-pin pushed in until the plunger drops into the hole that is drilled in the wrist-pin to receive it. This both locks the pin from end movement and turning. To remove the wrist-pin, a wire is inserted through a hole in the boss and the plunger is pushed up clear of the wrist-pin; then by tapping the end of the latter it may be made to move sufficiently to prevent the plunger from dropping back. The wire is then removed and the wrist-pin driven out.

Fig. 7 shows the wrist-pin held by a screw in the end of the connecting-rod, the screw fitting into a groove milled in the side of the wrist-pin. This differs from the previously mentioned wrist-pins, for it is free to turn in the piston bosses and is held in the rod end, thereby giving more bearing surface.

The method of holding by splitting the pin and internally threading the ends is shown in Fig. 8. The pin is held by screwing in taper plugs which spread the ends, making a tight fit in the bosses. The objection to this plan is that the plugs are liable to work loose and score the cylinder walls.

In Fig. 9 a screw in the end of a connecting-rod fits in a groove turned in the center of the wrist-pin as shown. This construction is similar to that of Fig. 7. The wrist-pin is free to turn in the bosses and also in the rod end, giving a very good bearing surface, but at the same time the pin is materially weakened by the circular groove.

A wrist-pin similar to that just described is shown in Fig. 10, only it is stronger. Instead of a central groove there is one at each end of the pin, though one would be sufficient; the set-screws prevent end movement.

Fig. 11 shows a wrist-pin with soft bronze ends which has free rotary and endwise play in both the rod and piston bosses. The bronze ends prevent scoring the cylinder walls, if the end of the wrist-pin should rub against them.

A wrist-pin that is flattened at each end and is held in place by a threaded ring or nut is shown in Fig. 12. It will be noticed that neither the wrist-pin nor nut can turn unless the connecting-rod turns also. In assemblying, the nut is slipped over the rod, the pin is inserted in the bearing and the rod is used to tighten up the nut.

A wrist-pin that is made straight and is free to turn in the rod end and bosses is represented by Fig. 13, kept in place by a ring which also acts as a packing ring.

A wrist-pin used by a prominent designer is shown in Fig. 14. The stepped end is a driving fit in the piston boss, and a pin used in the opposite end prevents turning.

Fig. 15 shows a straight pin held by a set-screw in the rod end.

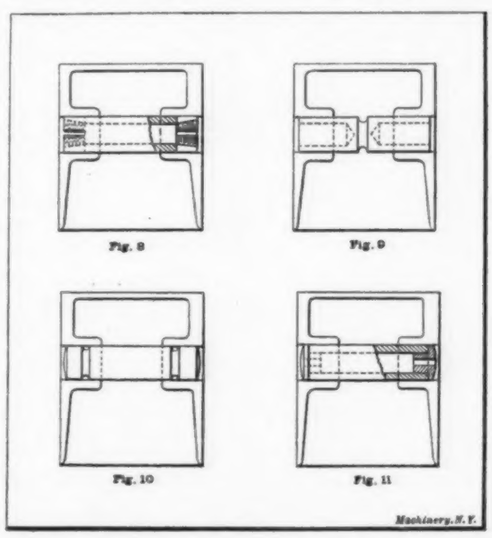


Fig. 8.—Hollow pin held by expanding plugs. Fig. 9.—Pin with circular retaining groove. Fig. 10.—Circular grooves in end of pin. Fig. 11.—Bronze-ended pin.

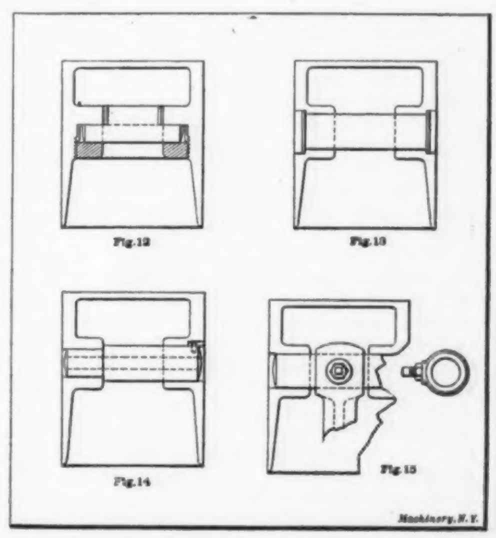


Fig. 12.—Nut method of securing pin. Fig. 13.—Pin with end bosses. Fig. 14.—Two-step pin with drive-fit end and key. Fig. 15.—Pin held by set-screw in end of piston-rod.

* Reproduced from *Machinery*.

Rubber Shoes

THE first so-called rubber shoes consisted mainly of a piece of caoutchouc, made by covering a clay form resembling a last with caoutchouc milk, and drying the resulting article over a fire. After the removal from the clay form the shoe was ready for use. It was a very durable affair, but at the same time was unsightly and uncomfortable. At the present time rubber shoes are made by coating cloth with just sufficient caoutchouc to make it waterproof. Some fabric having wide meshes is coated with a very thin layer of a soft rubber mass to which lampblack has been added. From this fabric the various parts used in building up the shoe are cut out and joined together on an iron last with the aid of a caoutchouc solution. The calendered sole is made of a tougher material. The shoes are coated with an asphalt varnish to give them a glossy appearance, whereupon they are removed to the vulcanizer (together with the lasts). The vulcanizer is very spacious, having a capacity for several thousand rubber shoes. The iron doors shut tight, steam is turned on and the whole is left to itself over night. The production of a day's work is thus ready the next morning, when the shoes are removed from the lasts and checked off.

The building up of a rubber shoe is rather tedious work. An ordinary shoe requires eight separate pieces, one with higher uppers consists of seventeen pieces and rubber boots are made of twenty-three separate parts, prepared and joined together by hand or machinery. Formerly the waterproofing was accomplished by placing a thin sheet of caoutchouc between two sheets of cloth and uniting them by passing the whole through heated rollers. Such fabric was extremely durable but very thick and heavy. Nowadays the waterproofing is usually done by coating the fabric with a solution of caoutchouc.—*Die Pflanze und der Mensch.*

The Properties of Selenium and Their Applications in Electrotechnics

By Erich Hausmann, Sc.D.

The peculiar property possessed by selenium of varying its electrical resistance on exposure to light has been known for over thirty-five years, but has only in recent years received an amount of attention proportionate to its importance; this being due perhaps to the use of selenium in light-telephony and in the electrical transmission of photographs.

In this article are given the results of experiments on this and other interesting properties of selenium carried out by many investigators and by the writer, the treatment of the subject being considered under three heads: I, the physical properties of selenium; II, influence of light on the electrical conductivity of selenium; and III, practical applications of this resistance variation in selenium.

PHYSICAL PROPERTIES OF SELENIUM.

The element selenium was discovered in 1817 by Berzelius, a Swedish scientist, as a by-product of the manufacture of sulphuric acid from iron pyrites. He observed that the physical properties of this element were somewhat similar to those of tellurium, which is named from the Latin "tellus," meaning earth, and he named this element selenium after the Greek Σελήνη, meaning moon, because of the close proximity of the satellite to the planet. Selenium is found in Vesuvian lava, in iron pyrites, and in natural sulphur of the Lipari Islands. It occurs also in the following rare minerals as a selenide: Eucarite, clausthalite, crooksite, riolite, lehrbachite, and zorgite. Although widely distributed geographically, selenium occurs only in small quantities, and is considered among the rare elements.

Selenium exists in four allotropic forms, which possess widely different properties, but these forms change readily from one to the other with the application of heat and subsequent treatment. These forms are:

First, amorphous selenium, which is a finely divided brick red powder. It is obtained as a by-product in the manufacture of sulphuric acid. This variety is non-metallic and a non-conductor of electricity.

Second, vitreous selenium, which may be obtained from the amorphous form by exposing it to a temperature of from 80 deg. to 100 deg. C. Vitreous selenium has a dark brown color and a smooth polished surface, and is the modification supplied commercially, either in the form of bars or granules. In very thin sheets it appears red to transmitted light. This fact, according to the electro-magnetic theory of light, precludes the electricity-conducting property of this variety of selenium. While in this condition it can be electrified by friction, like glass, and is a dielectric; the specific inductive capacity varying from 7.0 to 8.0. The melting point of this modification is 217 deg. C.

Third, fine-grained crystalline (α) selenium, which may be prepared from potassium selenide or obtained from vitreous selenium by heating at temperatures somewhat below 200 deg. C.; the transformation being most complete when prolonged heating at 195 deg. C. is followed by rapid cooling. Modification α is apparently a conductor of electricity, but this is held to be due to the admixture with selenides or selenium dioxide; so that this form is considered a non-conductor with a positive temperature co-efficient.

Fourth, coarse-grained crystalline (β) selenium is obtained from vitreous selenium by heating at temperatures above 200 deg. C., and subsequently cooling. The α modification also suffers transformation to the β modification treatment at a temperature above 160 degrees, followed by sufficiently rapid cooling. This form has a considerably better conductivity (1,500 to 2,000 times greater) for electricity than the foregoing modification, and within certain limits has a negative temperature coefficient of electrical resistance. Modification α is somewhat more soluble in carbon bisulphide than the β form. The latter is known as metallic selenium, but hereinafter the single term selenium will be used therefor. It is this metallic modification which is of interest from the electrical viewpoint.

The specific gravity at 25 deg. C. of both crystalline forms lies between 4.5 and 4.8, while that of the other modifications is 4.3. The specific heats of the crystalline varieties lie between 0.076 and 0.084, while that of the other forms is 0.095. The linear coefficient of expansion of crystalline selenium at 40 deg. C. is 0.0000368. The boiling point of selenium is 690 deg. C., and the atomic weight is 79.2.

The electrical conductivity of metallic selenium was first observed in 1851 by Hittorf, who also discovered the effects of temperature thereon. As a matter of fact, the specific resistance of selenium is very high; its value may be placed at about 2,500 megohms per centimeter cube.

In using selenium as a resistance material in connection with testing and signalling during the submersion of long submarine cables, Mr. May, an assistant of Willoughby Smith, experienced considerable difficulty in obtaining a constant resistance. He attributed the variation in resistance to the influence of light incident

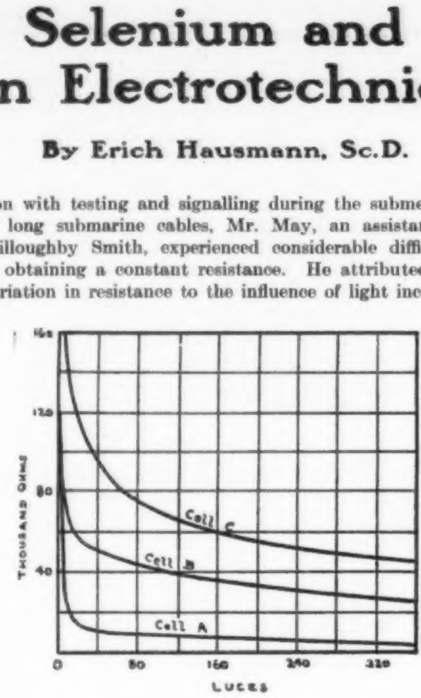


Fig. 1.

thereon, and showed that the resistance of selenium was lowered upon exposure to light. The announcement of this peculiar property was made by Smith to President Latimer Clark, of the Society of Telegraph Engineers of London, on February 12th, 1873; but little credence was given thereto until its verification by the Earl of Rosse, who proved that the phenomenon was due solely to light.

As selenium has a very high specific resistance, it becomes necessary in order to eliminate experimental difficulties, to construct rheostats of it in such a manner as to present numerous short paths for the current flowing between the terminals. Such arrangements are called selenium cells; the consideration of the construction thereof is here deferred until later.

INFLUENCE OF LIGHT ON ELECTRICAL CONDUCTIVITY OF SELENIUM.

The electrical resistance of selenium varies with the amount of light incident upon it; the resistance decreasing as the intensity of the light increases. The relation between these factors has been expressed by some of the earlier investigators to be that the resistance of a selenium cell is approximately inversely proportional to the square root of the light intensity. Hopius, however, gives as the result of his experiments that the resistance is approximately inversely proportional to the cube root of the light intensity. According to the researches of Ruhmer, Hesehus, Athanasiadis, and Minchin, the relation between selenium resistance and light intensity is a more complex one, and each has evolved an empirical equation therefor. The application of their formulæ depend upon the proper selection of one or more constants.

The electrical resistance of several selenium cells of widely different character under various illuminations as measured by some investigators and by the writer

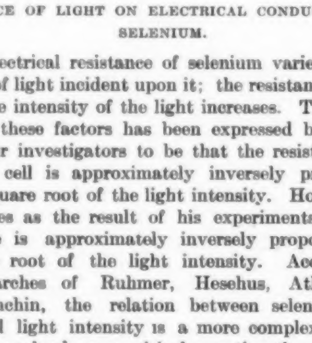


Fig. 2.

are given in the following tables (I, II, and III). The units of illumination employed are the lux, which is the light intensity at one meter's distance from a standard candle, and the foot-candle, which is the light intensity at a distance of one foot from a standard candle. The relation between these units is: Number of luces = 10.75 x number of foot-candles. The illumination values are calculated from the formulæ:

$$\text{Luces} = \frac{\text{candle power}}{(\text{distance in meters})^2} \text{ and}$$

$$\text{foot-candles} = \frac{\text{candle power}}{(\text{distance in feet})^2}$$

The observations recorded in Table III were obtained by the use of a galvanometer connected in series with a selenium cell to a 60-volt circuit. Readings of the meter were taken for various distances of a standard 16 candle-power electric lamp from the cell, sufficient time being allowed for the cell to assume its initial (dark) resistance between exposures.

TABLE I.—CELL A.

Ruhmer's* Cylindrical Cell (soft).

Illumination.			Resistance ohms.
160 c.p. lamp at distances d cm.	Luces.	Foot-candles	
	0	.0	120,000
400	1	0.093	42,000
283	2	0.186	32,000
200	4	0.372	25,000
100	16	1.490	15,000
50	64	5.95	9,000
25	256	23.8	5,000
10	1,600	149.0	3,050
2.8	20,400	1,897	1,500

TABLE II.—CELL B.

Ruhmer's* Flat Cell (hard).

Illumination.			Resistance (E.M.F. = 10 V.) ohms.
50 c.p. light at distances d cm.	Luces.	Foot-candles	
	0.	0.	100,000
350	4.09	0.381	75,000
300	5.56	0.517	70,000
250	8.00	0.744	66,000
200	12.50	1.162	60,000
150	22.2	2.064	54,000
100	50.0	4.65	47,000
50	200.0	18.60	35,000
40	312.5	29.1	30,000
30	555.6	51.7	26,000
25	800.0	74.4	23,000
20	1,250.0	116.2	20,000
10	5,000.0	965.0	14,000
5	20,000.0	1,860.0	6,000

TABLE III.—CELL C.

Otto Flat Cell. E. M. F. 60.1 volts.

Illumination.			Resistance in ohms.
16 c.p. light at distances d cm.	Luces.	Foot-candles	
	0.	0.	437,000
180	4.94	0.459	156,000
160	6.25	0.581	150,000
140	8.16	0.759	145,000
120	11.12	1.035	134,000
100	16.00	1.490	120,000
80	25.0	2.32	109,000
60	44.5	4.14	90,000
40	100.0	9.30	69,000
30	177.8	16.54	58,000
20	400.0	37.2	43,700

The current-measuring device was a sensitive D'Arsonval galvanometer, having 1,000 ohms resistance, which gave a deflection of one division for a potential difference of 0.0000111 volt. This instrument was connected to the terminals of an 0.888 ohm shunt that was in series with the selenium cell across the supply circuit. One division deflection of the galvanometer therefore corresponds to $\frac{1}{80,000}$ ampere.

The relations between selenium resistance and light intensity for these cells are shown graphically in Fig. 1; the curves therein embodying the foregoing experimental determinations.

EQUATIONS EXPRESSING RELATION BETWEEN SELENIUM RESISTANCE AND ILLUMINATION.

The expression first proposed for the relation between the electrical resistance of selenium and the intensity of

* Ruhmer, *Phys. Zeit.* V. 3, p. 468; *Elek. Zeit.* V. 25, p. 1021.

the light incident thereon, that the resistance is inversely proportional to the square root of the light intensity, may be expressed by the formula

$$R = \frac{a}{\sqrt{I}} \qquad (1)$$

where I is the intensity of illumination (here expressed in luces) and a is a constant; the term R being the resistance in ohms. This early equation does not give good results, and its use, even for rough approximations, is not recommended.

Another equation for the relation between selenium resistance and illumination, given by Hopius, may be expressed in terms of the same quantities as

$$R = \frac{b}{\sqrt[3]{I}} \qquad (2)$$

where b is a constant. Although this equation is of comparatively recent origin and much used, it is improbable that the relation between resistance of selenium and intensity of light can be such a simple one. It is, however, a very convenient expression and its use is recommended where moderate accuracy is desired.

Ruhmer's equation for the variation of resistance with light intensity is

$$R_1 = R_2 \left(\frac{I_2}{I_1}\right)^n$$

where R_1 is the ohmic resistance of selenium under illumination I_1, and R_2 is the resistance under illumination I_2; and n is a constant called the illumination exponent, which generally has a value between 0.25 and 0.40. The foregoing may also be written

$$R = \frac{c}{I^n} \qquad (3)$$

where c is a constant. It is evident that equations (1) and (2) are but particular cases of this expression in which the value of n is 0.50 and 0.33, respectively.

The expression of Hesehus for the dependence of electrical resistance upon illumination is given as

$$I = d(f^m - 1).$$

In this formula m is the relative change in resistance, or $\frac{R\text{ (dark)} - R}{R}$, where R is the ohmic resistance under illumination I (in luces). The quantities d and f are constants. Changing the form of this expression, there results

$$\frac{I}{d} + 1 = f^m$$

$$m = \log_f\left(\frac{I}{d} + 1\right) = \frac{\log_{10}\left(\frac{I}{d} + 1\right)}{\log_{10} f} \qquad (4a)$$

The resistance R is then obtained from the equation

$$R = \frac{R\text{ (dark)}}{m + 1} \qquad (4\text{ b})$$

The experiments carried on by Athanasiadis led him to propose the following expression for the variation of selenium resistance with intensity of illumination (in luces):

$$I = k(k - g)h$$

where k is the conductivity of selenium $\left(= \frac{10^6}{R}\right)$, and when g and h are constants. Solving for k, there results

$$k^2 - gk - \frac{I}{h} = o$$

whence

$$k = \frac{g}{2} \pm \frac{1}{2}\sqrt{g^2 + \frac{4I}{h}}$$

Since k must be greater than g, the positive sign is to be taken. Therefore

$$R = g + \frac{2 \times 10^6}{\sqrt{g^2 + \frac{4I}{h}}} \qquad (5)$$

The equation given by Minchin for the change of current through a selenium cell with changes in illumination, is

$$\log \frac{i}{i_0} = \left(\frac{I}{I_1}\right)^n \log \frac{i_1}{i_0}$$

where I_1 is the intensity of the light which alters the initial current i_0 (cell in darkness) to i_1, and I is the intensity of the light which alters i_0 to i, and n is a constant. Since resistance varies inversely as the current, this equation may be written, using similar subscripts

$$\log \frac{r_0}{r} = \left(\frac{I}{I_1}\right)^n \log \frac{r_0}{r_1} \qquad (6)$$

For a given cell r_0 is known, and, if the ratio $\frac{r_0}{r_1}$ be determined for illumination I_1, then the resistance r for illumination I may be computed.

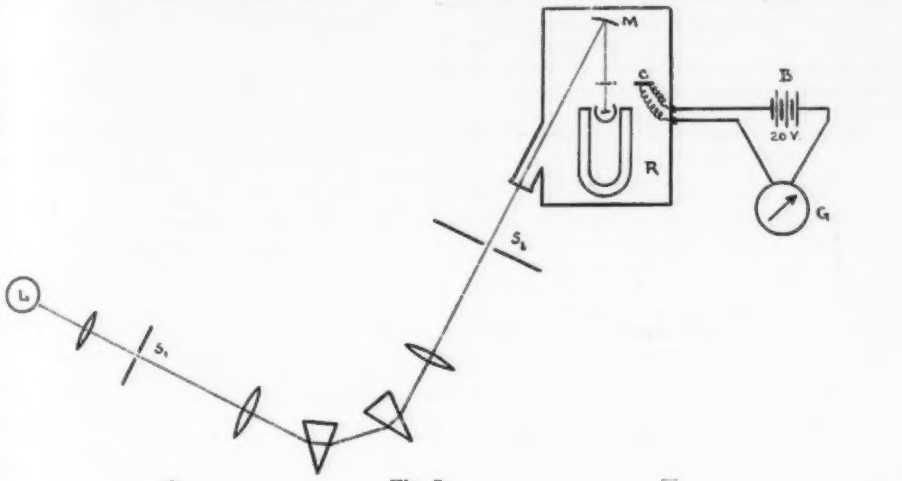


Fig. 3.

The last four equations are designed to give fairly accurate results when the proper constants have been chosen. In some of the equations this choice is more difficult to attain than in others. Which of these equations to employ for the predetermination of the electrical resistance of a selenium cell under a given illumination is a question which is subject to considerable discussion. This choice is often dependent upon the preference of simplicity to great accuracy.

SENSIBILITY OF SELENIUM CELLS.

The sensibility of a selenium cell is the ratio of its resistance in the dark to its resistance when exposed to a certain intensity of illumination. Absolute sensibility is the ratio of the dark resistance of a cell to its resistance in direct sunlight. The illumination produced by bright sunlight at noon during the winter months is approximately twenty thousand luces or about nineteen hundred foot-candles. The sensibility, therefore, of cell A is

$$\frac{120{,}000}{1{,}500} = 80.$$

and of cell B is $\frac{100{,}000}{6{,}000} = 16.6$

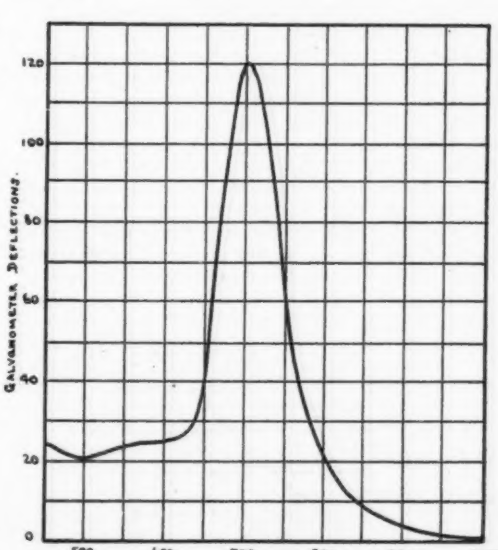


FIG. 4.

Selenium cells have been constructed by Ruhmer for his photophone experiments on the Wannsee, near Berlin, which have a sensibility of over 200.

SELENIUM RESISTANCE DEPENDENT UPON APPLIED VOLTAGE.

The fact that the resistance of selenium depends upon the impressed electromotive force was probably first observed by W. G. Adams, who found that the higher the battery power the lower was the resistance. The resistance of a piece of selenium, which was connected to a battery of Leclanché cells, he gives as

No. of cells.	Voltage.	Resistance (ohms).
5	7	5,400
30	42	4,600
35	49	4,400

Similar experiments have been performed by later investigators and their results confirm the hypothesis that with increasing voltage, or what is perhaps more correct, with increasing current, the resistance of selenium diminishes. Fig. 2 shows the relative conductivities of a selenium cell when connected successively to batteries of different voltages.

A complete statement of resistance change in selenium under exposure to light should therefore include the magnitude of the impressed E.M.F. employed in the measurement of the resistance.

SELENIUM RESISTANCE UNDER LIGHT OF DIFFERENT WAVE-LENGTHS.

With the same intensity of light, various portions of the spectrum affect to a greater or less degree the resistance of selenium. In determining the selective action of a cell it is essential that the energies of the radiation incident upon the cell be the same so that in the subsequent plotting of the results, a curve may be drawn showing the relation between resistance change and wave-length for constant radiated energy.

Experiments, carried out by Pfund to determine the variations of electrical resistance of selenium with wave-length of incident energy, have shown that while the blue and infra-red regions of the spectrum had but little effect, light of wave-length 7,000 tenth-meters (700 μμ) produced a considerable change in resistance. The apparatus used in a later determination[1] consisted of a spectroscope, a Boys radiomicrometer, and a D'Arsonval galvanometer which was connected in the circuit of the selenium cell; the arrangement of apparatus being shown in Fig. 3.

The light from a Nernst lamp L, after being concentrated on the slit S_1 of the spectroscope, is dispersed by the prisms and a bundle of homogeneous rays is transmitted through the slit S_2, then reflected from a short-focus concave mirror M, and finally becomes incident upon the blackened junction of the radiomicrometer R. The selenium cell C can be moved so as to intercept the beam of light, and the change of resistance is then indicated by a deflection of the galvanometer G. The energy carried by each bundle of homogeneous radiations before impinging upon the cell, was adjusted to the same value (3 centimeters deflection of R) by means of an optical wedge placed before the slit S_1. The selenium cell was then exposed until a maximum galvanometer deflection was recorded, the time of exposure to light being in some cases over three minutes. The results obtained are given in Table IV and are graphically portrayed in Fig. 4. Thus red and orange light are the most influential in producing change of resistance in selenium.

TABLE IV.

Wave-length inches.	Galv. defl. in mm.	Wave-length inches.	Galv. defl. in mm.
435	25	675	96
454	24	683	106
463	22	692	115
482	21	700	120
511	21	711	116
535	23	722	108
570	24	745	83
597	25	787	25
630	28	842	9
655	50	950	2
667	80	1,005	1

The sensibility of selenium cells containing highly purified selenium mixed with various metallic selenides was determined for different portions of the spectrum, and it was found that the position of the maximum in each case was at approximately 700 μμ. The conclusion is, therefore, that this position is not governed by metallic selenides, but by the pure selenium itself, since this was always present.

To be Continued.

Drier (Light Colored) for Varnish.—(a) Seven parts linseed oil, 3 parts chemically pure white lead, 1.5 part sugar of lead. (b) Seven parts linseed oil, 2 parts borate of manganese, 2 parts of zinc white. (c) Seven parts of linseed oil, 2 parts of borate of manganese, and 1.5 part sugar of lead.

[1] Pfund, Phys. Rev., v. 28, p. 324.

Geophysical Research*

Its Purpose and Methods

By Arthur L. Day

To write the history of the earth is a very different undertaking from writing the history of a people. In the latter case, a diligent seeker can usually find some ancient monastery where farsighted historians of an earlier generation have collected the more important records which he requires, and placed them within reach of his hand. With the earth's history, which is the province of geology, it is another matter. The great globe has been millions of years in the making, and except for a mere fragment of its most recent history, it has had neither a historian nor an observer. Its formation has not only extended over an almost incomprehensible interval of time, but we have no parallel in our limited experience to help us to understand its complicated development, and no system of classification adequate to the task, even of grouping in an orderly way all the observed rock and mineral formations with reference to the forces which molded them. And even if we could correctly interpret all the visible rock records, we are still quite helpless to comprehend all those earlier activities of the formation period, whose record is now obliterated.

To the student of the earth's history, therefore, the problem of gathering and ordering such a widely scattered and heterogeneous collection of effects and causes is one of somewhat overwhelming scope and complication. In the industrial world, a situation of this kind soon results in replacing individual effort with collective effort, in the organization of a system of a scope more appropriate to the magnitude of the task. We are familiar with industrial organization and the wonderful progress in the development of American industries which has everywhere followed it. We are also familiar with organized geological surveys and the success which has attended them in geological and topographical classification. But the idea of organizing research to meet a scientific situation of extraordinary scope and complexity is still comparatively new. The very words science and research are still regarded as referring to something out of the ordinary, something to be withheld from the common gaze, to be kept hidden in a special niche, behind a mysterious curtain and served by priests of peculiar temperament and unpractical ideals. This is both disparaging to our good sense and prejudicial to the progress of knowledge. Scientific research is not a luxury; it is a fundamental necessity. It is not a European fad, but is the very essence of the tremendous technologic and industrial success of the last twenty years, in which we have shared.

Prof. Nichols, of Cornell, as retiring president of the American Association for the Advancement of Science, put the case in this way: "The main product of science (research) . . . is knowledge. Among its by-products are the technologic arts, including invention, engineering in all its branches, and modern industry." The idea of scientific research is therefore not less tangible than industrial development, or less practical; it is merely one step more fundamental; it is concerned with the discovery of principles and underlying relations rather than their application. This being true, research should profit as much, or even more, from efficient organization as industrial development has done.

Although this conclusion is making its way but slowly in American science, in geological research, where material must be gathered from the utmost ends of the earth and even from within it, and where nearly every known branch of scientific activity finds some application, there is a peculiarly favorable opportunity for organized effort which is already coming to be recognized. "So long as geology remained a descriptive science," says President Van Hise of Wisconsin, "it had little need of chemistry and physics; but the time has now come when geologists are not satisfied with mere description. They desire to interpret the phenomena they see in reference to their causes—under the principles of physics and chemistry. This involves co-operation between physicists, chemists and geologists."

In a general way, physics, chemistry and biology have already supplied working hypotheses which have been used by students of geology to help in the examination, classification and mapping of the most conspicuous features of the exposed portion of the earth. The geologist has gone abroad and has studied the distribution of land and water, the mountain ranges, the erosive action of ice and of surface water and the resulting sedimentary deposits, the distribution of volcanic activity and of its products, the igneous rocks; or more in detail he has studied the appearance of fossils in certain strata, and has inferred the sequence of geologic time. The distribution of particular minerals and of ore deposits has been carefully mapped. Regions which offer evidence of extraordinary upheaval through the exercise of physical forces have been painstakingly examined, and so on through the great range of geologic activity. In a word, the field has been given a thorough general examination, but the manifold problems which this examination has developed, although early recognized, and often the subject of philosophical speculation and discussion, still await an opportunity for quantitative study. They are often problems for the laboratory and not for the field, problems for exact measurement rather than for inference, problems for the physicist and chemist rather than for the geologist. This is not a result of oversight, it is a stage in the development of the science, first the location and classification of the material, then the laboratory study of why and how much.

Certain indications have led us to believe, for example, that the earth was once completely gaseous and in appearance much like our sun. Indeed, it possibly formed a part of the sun but through some instability in the system became split off—a great gaseous ball which has cooled to its present condition. The cooling probably went on rapidly at first until a protecting crust formed about the ball, then more and more slowly, until now, when our loss of heat by radiation into space is more than compensated by heat received from the sun. Obviously, the earliest portions of this history are and must remain dependent upon inference but the formation of a solid crust cannot advance far before portions of it become fixed in a form such that further disturbance does not destroy their identity. From this point on the history of the earth is a matter of record and can be interpreted if only we have sufficient knowledge of the mineral relations through all the stages of their development.

It must have been a very turbulent sea, the molten surface of our earth upon which the rocky crust began to form. The first patches of crust were probably shattered over and over again by escaping gases and violent explosions of which our waning volcanic activity is but a feeble echo. If the earth was first gaseous, and the outer surface gradually condensed to a liquid, its outer portions at least must have been whirled and tumbled about sufficiently, even in a few thousand years (which is a very small interval in the formation of an earth) to mix its various ingredients pretty thoroughly. It has accordingly been hard to see just how it came to separate into individual rocks of such widely different appearance and character. Of course the number of its ingredients was large. We have already discovered eighty or more different elementary substances in the earth, and there is an almost endless number of more or less stable compounds of these. The freezing of an earth is therefore different from the freezing of pure water, but the freezing of salt water offers a clue to the explanation of the way in which the earth solidified as we find it. When salt water freezes, the salt is practically all left behind. The ice contains much less salt and the remaining water relatively more salt than before freezing began. Applying this familiar observation to the molten surface of the earth as it begins to solidify, we have a suggestion of order and reason in its separation into so many kinds of rocks.

Now, it happens that in the recent development of chemistry much attention has been given to the study of solutions of various kinds, and a great body of information has been gathered and classified of which our observation upon the freezing of salt water is a simple type. Still more recently (quite lately in fact) it has occurred to many students of the earth that here lies not only the clue but perhaps the key to their great problem. If the individual components which are intimately mixed in solution separate wholly or partially in some regular way upon freezing—and nearly all the solutions which have been studied appear to show such segregation—we have a quantitative system which will probably prove adequate to solve the problem of rock formation, provided only that the experimental difficulties attending the study of molten rock and the complications imposed by the presence of so many component minerals, do not prove prohibitive. This is a very simple statement of the point of view which has led to the experimental study of rock formation in the laboratory as a natural sequence to statistical study in the field.

Geophysics therefore does not come as a new science, nor as a restricted subdivision of geology, like physiography or stratigraphy, but rather to introduce into the study of the earth an element of exactness, of quantitative relation. It may include physics or chemistry, biology or crystallography or physical chemistry, or all of these at need. The distinctive feature of geophysics is not its scope, which may well be left to the future, but its quantitative character. The Geophysical Laboratory of the Carnegie Institution at Washington has entered upon some of the investigations suggested by this long preliminary study of the earth—the physical properties and conditions of formation of the rocks and minerals. The Department of Terrestrial Magnetism of the same institution has undertaken another—the earth's magnetism; the German Geophysical Laboratory at Göttingen a third—the earthquakes—and these will, no doubt, be followed by others.

The first effect of calling exact science into consultation upon geologic problems is to introduce a somewhat different viewpoint. It has been our habit to study the minerals and the rocks as we find them to-day, after many of the causes which have had a share in their evolution have ceased to be active—after the fire has gone out. If we attempt to reconstruct in our minds the operations which enter into the formation of an igneous rock or of a body of ore, we must infer them from present appearances and environment. The experimental geophysicist, on the other hand, confronting the same problem, says to himself: Can we not construct a miniature volcano in the laboratory; Can we not build a furnace in which an igneous rock can be formed under such conditions that we can observe its minutest change? He proposes to introduce temperature measuring devices and apparatus for the determination of pressure, to investigate the character of the surrounding atmosphere and the quantity of water vapor which may be present. He insists upon the chemical purity of every ingredient which goes into the furnace and guards it carefully against contamination. In these various ways he will undertake to ascertain the exact magnitude of all the causes, both physical and chemical, which have been at work in his miniature rock-producer, together with the physical characteristics of the product.

A very practical question now arises. Can he do all this successfully at the temperatures where the minerals form? We must press this question and insist upon a satisfactory answer, for it is by no means obvious that the relations which the physicist and chemist have established at the temperatures of everyday life—energy content, density, solubility, viscosity, dissociation—will continue to hold when substances are carried up to a white heat. The substances, too, are different from those with which the chemist and physicist have been generally familiar. Instead of simple metals, aqueous solutions, and readily soluble active salts, we encounter silicates and refractory oxides, inert in behavior and capable of existing together in mixtures of great complexity. We must, therefore, extend the range of our physics and our chemistry to a scope in some degree commensurate with the wide range of conditions which the earth in its development has passed through. Let us follow for a little the actual progress of such an attempt.

The first step is to provide the necessary temperatures. Obviously, the common fire-clay crucible and the smelter's furnace with its brick lining, will not serve us, here, for all these are themselves mineral aggregates. The charge, furnace lining, and crucible would go down together in a fall as disastrous as Humpty Dumpty's. But experiment has taught us that platinum crucibles, magnesia furnace tubes inclosing an electrically-heated helix of platinum wire, and electric temperature-measuring devices, provide a furnace in which nearly all of the important minerals can be successfully studied, which is not enough to melt zinc, silver, gold, copper, nickel or iron readily, and where any temperature up to 1,600 deg. Cent. can be maintained perfectly constant if need be for several weeks. All these temperatures can be measured with no uncertainty greater than 5 degrees. This equipment preserves the chemical purity of the mineral studied, and enables the temperature to be controlled and measured at every step of the experimental work. Or an iridium furnace tube and an iridium crucible can be substituted for platinum, the magnesia supports can still be used, and we can go on to 2,000 deg. Cent., which is quite sufficient for all the more important minerals which we know.

The physicist has, therefore, found a suitable melting pot, and means of ascertaining what goes on within the pot; but he at once encounters another difficulty. Nature has provided us with relatively few minerals of high chemical purity. If a natural mineral is chosen for experiment, however typical it may be, several per cent of other minerals may be expected to be present with it, the effect of which is at present quite unknown.

*Presidential address delivered at the 700th meeting of the Philosophical Society of Washington, November 25th, 1911, and published in the *Journal of the Washington Academy of Science*.

Now, the first axiom of the investigator in a new field who desires to undertake measurements which shall have a real value, is that the number of unknown quantities in his equations must not be greater than he can eliminate by his experimental processes; in other words, he must begin with conditions so simple that the relation between a particular effect and its cause can be absolutely established without leaving undetermined factors. Having solved the simple case, it is a straightforward matter to utilize this information to help solve a more complicated one. If we would, therefore, reduce the mineral relations to an exact science, which is our obvious purpose, it is necessary from the outset to prepare minerals of the highest purity and to establish their properties. Having obtained such a pure mineral type, it may be, and often is, in the power of the mineralogist and his microscope to determine, by direct comparison with its natural prototype, the kind and amount of effect actually produced in the natural mineral by the one or more other minerals which it contains. We have, therefore, hardly started upon our investigation before the need of an organized system is demonstrated, first comes the chemist, who prepares and analyzes the pure mineral for investigation; then the physicist, who provides and measures the conditions to which it is subjected; then the mineralogist, who establishes its optical properties in relation to the corresponding natural minerals.

Having prepared such a mineral, of high purity and of known crystalline character, we can ascertain its behavior at the temperatures which must have obtained during the various stages of earth formation. We can study the various crystal forms through which it passes on heating and the temperature ranges within which these forms are stable; we can also melt it and measure the melting or solidifying temperature. Another mineral, prepared with the same care and studied in the same way, may afterward be added to the first, and the relation of these two determined. If they combine, heat is absorbed or released; and this quantity of heat can be measured, together with the exact temperature at which the absorption or release takes place. If the mixture results in the formation of one or more mineral compounds, we shall learn the conditions of formation, the temperature region within which the new forms are stable, and the changes which each undergoes with changes of pressure and temperature, as before. If the new forms show signs of instability, we can drop them into cold water or mercury so quickly that there will be no opportunity to return to initial stable forms, and thus obtain, for study with the microscope at our leisure, every individual phase of the process through which the group of minerals has passed.

Without complicating the illustration further, it is obvious that we have it in our power to reproduce in detail the actual process of rock formation within the earth, and to substitute measurement where the geologist has been obliged to use inference; to tabulate the whole history of the formation of a mineral or group of minerals under every variety of condition which we may suppose it to have passed through in the earth, provided only we can reproduce that condition in the laboratory.

During the past quarter of a century, there has arisen in the middle ground between physics and chemistry a new science of physical chemistry, in the development of which generalizations of great value in the study of minerals have been established. As long ago as 1861 the distinguished German chemist, Bunsen, pointed out that the rocks must be considered to be solutions and must be studied as such; but inasmuch as comparatively little was known about solutions in those days, and the rocks at best appeared to be very complicated ones, no active steps in that direction were taken during Bunsen's life. But in recent years solutions have been widely studied, under rather limited conditions of temperature and pressure, to be sure, but it has resulted in establishing relations—like the *phase rule*—of such effective and far-reaching character, that now, just half a century afterward, we are entering with vigor upon the prosecution of Bunsen's suggestion. It is now possible to establish definite limits of solubility of one mineral in another, and definite conditions of equilibrium, even in rather complicated groups of minerals, which enables us not only to interpret the relations developed by such a thermal study as that outlined above, but also to assure ourselves that only a definitely limited number of compounds of two minerals can exist, that they must bear a constant and characteristic relation to each other under given conditions of temperature and pressure, and that changes of temperature and pressure will affect this relation in a definite and determinable way. Physical chemistry not only takes into account the chemical composition of mineral compounds, but their physical properties as well, throughout the entire temperature region in which they have a stable existence, and therefore furnishes us at once with the possibility of a new and adequately comprehensive classification of all the minerals and rocks in the earth. The value of an adequate system of classification appeals chiefly to those whose duties bring them into intimate relations with the subject matter of a science, but so much may appropriately be said, that a consistent application of physical chemistry to the minerals may operate in the not far distant future to develop an entirely new conception of the science of mineralogy.

As the number and scope of such exact measurements increase, we gradually build up what may be called a geologic thermometer. Just as the location of fossils offers a basis for estimating geologic time, it often happens that a mineral takes on a variety of different crystal habits, according as it happened to form at one temperature or another. Quartz, for example, which is one of the commonest of natural minerals and one of the most familiar, undergoes two changes in its crystal form which leave an ineffaceable record. One occurs at 575 degrees and the other at 800 degrees. An optical examination of even a minute quartz fragment from the mountainside will reveal to the skilful petrologist whether the crystal formed at a temperature below 575 degrees, between 575 degrees and 800 degrees, or above 800 degrees. And if we could have at our disposal a great body of such exact measurements of the temperature region within which particular crystals originate and remain stable, we could apply that directly to terrestrial formations in which this mineral occurs, and read therein the temperature which must have obtained during their formation. All this will not be done in the first year, and perhaps not in the first decade; but the ultimate effectiveness of this method of procedure in establishing the relations between the minerals and the valuable ores is as certain of success as the operations of any of the sciences which have now come to be characterized as exact, as opposed to descriptive.

There is one important difference between the great laboratory of nature and its feeble human counterpart. Nature operated with large masses, mixed with a generous hand, and there was always plenty of time for the growth of great individual crystals, at which we marvel whenever we encounter them, and which we have sometimes come to regard highly as precious stones. To carry these processes into the laboratory is necessarily fraught with certain limitations. The quantities must remain small and the time and available financial resources will always be limited. So long as we are able to ascertain the optical character of a crystal with equal exactness whether the crystal is of the size of the proverbial mustard-seed or a walnut, the scientific laboratory cannot properly afford the time necessary to produce the large crystals which nature offers so abundantly. Furthermore, the crystals of nature often owe their brilliant coloring to slight admixtures of impurity, which, to the scientific laboratory, spell failure and are avoided with the utmost care. Most of the mineral crystals, when reproduced in the laboratory, are quite colorless. And so, although the question is often raised whether we are not really engaged in the artificial production of gems, and although the seductive character of such an investigation would no doubt appeal to many, it must be admitted that the geological laboratory is not and probably will never become the serious competitor of nature in those directions in which nature has produced her most brilliant effects.

In what has preceded, I have laid emphasis upon the value of experimental measurements in the systematic development of a more exact science of the earth. It is a fair question, and one which is very often raised, whether all this investigation has a utilitarian side, whether the knowledge obtained in this way and with such difficulty, will help to solve any of the problems arising in the exploitation of our mineral resources or assist in our industrial development. It is neither wise nor expedient, in entering upon a new field of research, to expatiate long upon its practical utility. Its principles must first be established, after which there is no lack of ingenuity in finding profitable application of them.

The development of thermoelectric apparatus for the accurate measurement of high temperatures was begun and has been perfected in the interest of geophysical research, and it has already found such extended application among the technical industries as to demand the manufacture and calibration of thousands of such high temperature thermometers every year. The tempering and impregnation of steel are no longer dependent upon the more or less trained eye of the workman, but are done at measured temperatures and under known conditions which guarantee the uniformity of the product and admit of adaptation to particular purposes, like high speed tools or armor plate. This has the incidental but far-reaching industrial consequence that workmen of great individual skill in these industries are much less necessary now than formerly. Everything is accomplished by bringing temperature conditions under mechanical control and making them absolutely reproducible without the exercise of critical judgment on the part of anyone.

A more intimate knowledge of the behavior of the minerals themselves finds almost immediate industrial application. An industry which has grown to enormous proportions in recent years is the manufacture of Portland cement, about which little more has been known than that if certain natural minerals were taken in the proper proportions and heated in a peculiar furnace developed by experience, the resulting product could be mixed with water to form an artificial stone which has found extensive application in the building trades. Chemical analysis readily established the fact that the chief ingredients in a successful Portland cement were lime, alumina and silica, with a small admixture, perhaps, of iron and magnesia; but the relation in which these ingredients stood one to another, that is, which of them were necessary and which merely incidental, and in what compounds and what proportions the necessary ingredients required to be present, has never been satisfactorily established. When we know the stable compounds which lime, alumina and silica can combine to form, together with the conditions of equilibrium between these for different temperatures and percentages of each component, a formulæ can be written offhand for a successful Portland cement from given ingredients somewhat as an experienced cook might write out the recipe for a successful dish. Such definite and valuable knowledge is not beyond our reach. To obtain it requires, in fact, precisely the same system of procedure which has been described above and which has already been successfully applied to many of the natural minerals which have been reproduced and studied in the Geophysical Laboratory during the past five years. It happens that we have examined a considerable number of these very mixtures in our recent work upon the rocks. All the compounds of lime, silica and alumina have been established, and a portion of the silica-magnesia series, and their relations have been definitely determined throughout the entire range of accessible temperatures. There is no reason to apprehend serious difficulty in applying the same procedure to the commercial ingredients of Portland cement, and replacing the present rule-of-thumb methods and uncertain products with dependable cements. The problem of determining the relation of the ingredients in commercial cement and the conditions necessary for its successful formation is exactly the same in character as that of determining the conditions of formation of the rocks of the earth.

A physico-chemical investigation of the sulphide ores over a wide range of temperatures and pressures has also been undertaken, which has developed a large body of exact information of value in mining industry. And such illustrations could be continued almost indefinitely, if it would serve any useful purpose to do so.

The industrial world is not, as a rule, interested in scientific principles; the principle must first be narrowed down to the scope of the industrial requirement before its usefulness is apparent. The immediate effect of an industrial standpoint is, therefore, to restrict investigation at the risk of losing sight of underlying principles entirely. An illustration of this has come down to us through the pages of history, of a character to command and receive the utmost respect, for such another can hardly be expected to occur. We have honored the early philosophers for their splendid search after broad knowledge; but in what is now the field of chemistry, they allowed themselves to be turned aside to the pursuit of a single, strictly utilitarian problem—the transmutation of base metals into gold. The history of chemistry is a history of this one problem from the fourth to the sixteenth century, twelve centuries before a man arose whose broader standpoint enabled him to divert the fruitless search into other channels from which a science has slowly arisen which is now so broad as to overlap most of the other sciences, and withal so practical that hardly an industry is entirely independent of it.

The so-called practical questions may therefore as well be left to take care of themselves. There has been no lack of ingenuity in making profitable application of systematic knowledge whenever the need for it became insistent, for the rewards of such effort are considerable. And it is no longer an argument against proceeding to establish relationships in a new field, that the scope of their application cannot be completely foreseen.

Now, what more promising questions occur to one than these: If the earth was originally fluid, as it appears to have been, and has gradually cooled down to its present state, its component minerals must at some time have been much more thoroughly mixed than now; how did they come to separate in the process of cooling into highly individualized masses and groups as we now find them, and what were the steps in their deposition? If the whole earth was hot, whence came the marble of which we have so much and which can withstand no heat? What has given us the valuable deposits of iron, of gold, of precious stones? What determines the various crystal forms found in the different minerals, and what is their relation? Some must have formed under pressure, some without pressure, some with the help of water, and some without. Where is the center, and what the source of energy in our volcanoes? All these questions, and many more, the geophysicist may attempt to answer.

The Value of Birds to Man*

VEGETATION is the prime requisite for the perpetuity of all other forms of life upon the earth. The greatest known enemy to vegetation is insect life, while bird life, by virtue of its predominating insect diet, wields a most important balance of power against the ravages of this the chief pest of vegetation.

The number of insect species is greater by far than that of the species of all other living creatures combined. The voracity of insect life is as astonishing as its power of reproduction. Many caterpillars consume twice their weight in leaves per day, which corresponds to a horse eating daily a ton of hay.

The development of young birds is so rapid, and the demand upon the vitality of older ones so great, that an enormous amount of food is necessary to sustain the vital processes. Digestion is exceedingly rapid in birds; and they feed for the most part throughout the day, especially when rearing young. The number of insects daily passed into the insatiable maws of the nestlings during this period almost exceeds belief. But the most valuable services of the adult bird are rendered when it is feeding in winter or early spring, for then it destroys countless numbers of insects in the embryo state, and thus prevents myriads of depredators from coming forth. Grave and far-reaching results invariably follow the suppression of this perennial regulative influence which is exerted by birds individually everywhere as a check on insect life.

Forest trees have their natural insect foes, to which they give food and shelter; and these insects in turn have their natural enemies among the birds, to which the tree also gives food and shelter. Birds are not only essential to the well-being of the tree, but the tree is necessary to the life of the bird. Call the bird in the orchard an evil if you will. But it is a necessary evil, and the fruit-grower must make up his mind to pay the bird its wages, even though at times they may seem exorbitant.

Each season, until hay-making commences, the grass offers cover and shelter for the nests of such birds as breed on the ground. The fields also provide food for birds, and for the insects on which birds feed. Where the birds of the field are undisturbed they tend to hold the grass insects in check. On the other hand, when the numbers of birds in the field are, for any reason, insufficient, the insects increase.

Without birds grass could not be grown. The grub of a single species of beetle, if unchecked, could destroy all the grass roots of our meadows, or any one of the several species of cut-worms might be sufficient to destroy all the verdure above ground.

The destructive habits of the small rodents, which are the natural prey of hawks and owls, are much the same all the world round. Here in England—though on account of their small size and secretive habits they are often undiscerned by man's dull eyes—they swarm in such numbers in the fields and hedgerows that the damage they do must prove a steady drain on the resources of the farmer. The number of small rodents eaten by the rapacious birds is almost as remarkable in proportion to their size as is the number of insects eaten by small insectivorous birds.

The young of hawks and owls remain a long time in the nest, and require a great quantity of food. During this period the resources of the parents must be taxed excessively in the effort to satisfy the hunger cravings of their offspring, and it is not to be wondered at if some individuals are forced occasionally to snap up a chicken. But what is the worth of the chicken, or of the young pheasant, occasionally taken, compared with the hundreds of thousands of pounds' worth of damage that is wrought in the orchards and fields by rodents that hawks and owls, had they been spared, would have fed upon for the maintenance of their species?

The destruction of the white heron for its scapular plumes has robbed half the world of a bird which is most useful to man. Its loss to India and to China is most serious. It never touches grain, but feeds solely near water and over damp ground, the breeding-places of innumerable batrachians, small crustaceans, and pestiferous insects, all of which directly or indirectly injuriously affect crops in the neighborhood. The presence of the white heron in the rice-fields, for instance, is distinctly beneficial to the farmer, and rice is one of the most extensively grown crops of India and of China.

Turning to Australia, it may be mentioned that the slaughter of this and other wading birds for their plumage is causing in that country a decline in its fish resources. As these birds grow fewer in numbers, so do the crustaceans that destroy the fish spawn increase in hosts.

The gull is a surface feeder. It may occasionally levy toll on useful fish when they are indiscreet enough to come to the surface of the water, but to say that they do any appreciable injury to the fishery business is absurd. On the other hand, the presence of the gull is essential to man's health. While the bird fulfills many useful minor offices, such as destroying larvæ inland along the seaboard, and in eating enemies of fish that are exposed during low tide, its chief function in the economy of nature is that of scavenger of the harbors and of the littoral, just as vultures are the scavengers of the mainland.

Birds, unquestionably, are one of man's greatest possessions; yet it is just the possession on which he often sets the least value.

* From a paper read before the British Empire Naturalists' Association on December 1st by James Buckland, and abstracted in *Nature*.

Science Notes

Coloration of Glass by Colloidal Particles.—Through the work of Zsigmondy and his followers on ultra-microscopic particles, the attention of the public has been drawn to glass colored by colloidal metals. Textiles also are sometimes colored in this way. According to a note in *Cosmos*, we have here an example of the truth of the old saying, "There is nothing new under the sun." In an English work on electricity by Tiberius Cavallo, published in the eighteenth century, nearly one hundred and twenty years ago, we find the following two recipes: "Take two very thin sheets of window glass, and between them insert gold or silver foil or the like. Then place the sheets in a press and connect the metal foil with an electric condenser, such as a Leyden jar. When the latter is highly charged, and the discharge is allowed to take place through the metal foil, the glass is very apt to break. If, however, one succeeds in allowing the discharge to pass without breaking of the glass, the metal vaporizes into the glass sheet, which then acquires an insoluble and highly tenacious coloration." The other recipe is as follows: "Upon a well stretched silk fabric place a stencil pattern, and over this some gold leaf. If a sufficiently strong electric discharge is passed through the gold, the latter is vaporized and, passing through the openings in the stencil, forms a gilt pattern upon the silk."

Pancreatin and Pepsin.—It is often supposed that the digestive power of pancreatin and pepsin are opposed to one another. According to the United States Pharmacopœia, "in neutral alkaline solution pancreatin destroys pepsin, and in acid solution pepsin destroys pancreatin." M. A. Zimmerman, however, in the *Journal of Industrial Chemistry*, tells us that this mutual destructive action does not, in fact, occur, and the two substances can be kept together in the same solution for years. It appears further that the acid of gastric juice in the stomach combines with the proteids, and then does not destroy pancreatin, which hydrolyzes starch, especially in a feebly acid medium. Pepsin and pancreatin can be administered together in a suitable acid solution, or else mixed together dry in all proportions. Pepsin under these conditions retains all its proteolytic and pancreatin all its amylolytic and tryptic power. Hydro-chloric acid exerts an accelerating influence upon the power of pancreatin and malt of hydrolyzing starch. Very small proportions of hydrochloric acid are sufficient to exert this influence. The temperature is a very important factor; a starch paste made up with 16 parts of water and 1 of starch should have a temperature of 50 deg. Cent.; the pancreatin solution should not exceed 21 degrees, and the final temperature 45 deg. Cent.

Action of Distilled Water upon Marine Organisms.—Generally speaking, marine animals, if suddenly placed in distilled water, are fatally affected; as a matter of fact, even for fresh water animals distilled water is more or less poisonous. In this respect, however, great differences are shown in the behavior of different species. Thus, according to Loeb, a small fish, Fundulus, which ordinarily develops and lives exclusively in sea water, can be kept in distilled water without any apparent discomfort or injury to this organism. Its eggs, if placed in distilled water, develop in the ordinary fashion. In fact, Loeb has used this experiment to reply to an objection which had been made with regard to his researches on the antagonistic action of salts. The Fundulus, if placed in a solution of pure sodium chloride, isotonic with sea water, very soon dies, but if a little potassium or calcium salt is added to the solution, the fish prospers, because, according to Loeb, the last mentioned salts in some manner counteract the effect of sodium chloride. On the other hand, it may be urged that Fundulus needs the potassium or calcium salts for its existence. This supposition is contradicted by the experiment with distilled water, for if the fish can live in distilled water, it is evident that they are not in need of the potassium salts. At the same time, it must be mentioned that other researches, conducted by Stockard, on the action of distilled water upon Fundulus have not led to the same results. According to this experimenter the larvæ are killed by distilled water in three days. In view of this Loeb has repeated his experiments with great care, and his results confirm his earlier conclusions. In fact, Loeb has shown that an adult Fundulus can be transferred abruptly from sea water to distilled water, after having carefully washed off all the sea water adhering to it. Such a Fundulus may continue to live without showing any signs of ill effects five weeks and longer. However, all adults are not equally resistant to this change. Loeb ascribes the divergent results of Stockard to the fact that he did not purify the distilled water with sufficient care.—*La Nature.*

Trade Notes and Formulæ

Composition for Machine Driving Belts.—Gutta percha, 70 to 75 parts; rubber, 25 to 30 parts; sulphate of antimony, 4 to 5 parts; sulphur, 1 to 2 parts.

Transfer Color.—Two parts tallow, 1 part rosin, 2 parts shellac, 1 part Venice turpentine, 2 parts lampblack; melt and mix. For zinc transfers, add 1 part yellow wax, 2 parts Burgundy pitch, melted over a coal fire in an iron pot, and then the mass for the transfer rubbed down on a plate with about one-third of ordinary drawing ink.

Rubber Dressing for Driving Belts.—Melt 0.5 part of elastic rubber, finely cut, in a well-closed iron kettle at 50 degrees Cent. (122 degrees Fahr.) over a coal fire, with 0.5 part of oil of turpentine. Then add 0.4 part of rosin, well stirred until it melts, and 0.4 part of yellow wax. Next, in a suitably large pot, place 1.5 parts of train oil and 0.5 part of tallow, heat until melted, then while stirring, add the second mixture to the first and continue to stir.

Drier for Lacquers.—Mix French or American rosin intimately with lime-paste, allow it to stand 24 hours, evaporate it to dryness on an iron plate and pulverize. For instance, for a quick drying japan varnish of soft rosin varieties: 100 parts fir pitch, rosin or turpentine are melted gradually, stirring the while, and 10 to 15 parts of the above powder added; this is heated for half an hour, removed from the fire and 25 to 30 parts linseed oil and 35 to 90 parts of oil of turpentine added as required.

Imitation Ostrich Plumes.—From floss silk, a product resembling a little barb of the genuine ostrich feather is woven on a loom. In the center of this ramus is placed a tinned wire, fine as a hair, and a fine silk thread, which holds the separate fibers together. In making up this plume, take the feather-like fabric, stretch it carefully in a frame having the form of a feather and weave through the center twice with two strands of wire, fine as hair. Then in the center of the fabric, attach a silken or swan's quill (split), smooth off uneven places and curl with a round iron.

Self-inking Pad.—Permanent self-inking stamp pads are made as follows: Boil 35 grammes of Japanese gelatine (agar-agar) with 3 liters of water, agitating all the while to prevent burning, until completely dissolved. While still hot strain through flannel, then mix with 600 grammes of glycerine and boil down to 1,000 grammes (total weight). Add 60 grammes of methyl violet 3B (or some other coal tar dye) and stir until dissolved. Pour this solution into a flat tin box and allow to cool off; then cover surface with muslin or finished calico. If in the course of time the surface should dry out, moisten with a few drops of water or glycerine and the pad is again ready for use. —*Pharmaceut. Zeitung.*

Thermal Measurement of Luminous Efficiency.—The *Elektrotechnische Zeitschrift* has recently published an article, by Dr. Johannes Russner, on certain measurements of the luminous efficiency of incandescent lamps made thermometrically. The lamp, without socket, is immersed in a 30 per cent solution of ferro-ammonium sulphate, to a layer thickness of 30 millimeters (1.2 inch). Such a layer has the property of absorbing passing non-luminous heat almost completely, while at the same time it is fairly transparent to luminous rays. The elevation of temperature in the solution is measured with the incandescing lamp inserted in the same for a definite interval of time. The test is then repeated with the lamp coated in blackened tinfoil, to prevent the escape of light through the solution, and the increase of corresponding temperature elevation is noted. The difference of the two temperature elevations, corrected for outstanding sources of error, then enables the luminous efficiency of the lamp to be determined. The results, given in the article, go to show that the luminous efficiency of certain 115-volt carbon-filament lamps averaged 1.6 per cent, and that of certain 115-volt metallic-filament lamps averaged 4.5 per cent, or nearly three times as much.—*Electrical World.*

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